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ANALYSIS OF ENERGY RESOURCES AND PROGRAMS OF THE SOVIET UNION AND EASTERN EUROPE. APPENDIX F: ELECTRIC POWER

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Stanford Research Institute

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ANALYSIS OF ENERGY RESOURCES AND PROGRAMS OF THE SOVIET UNION AND EASTERN EUROPE

Appendix F: Electric Power

Stanford Research Institute

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The objective of this study was to conduct an analysis of the energy resources and programs of the Soviet Union and Eastern Europe and their relationship to the rest of the world. A survey was made of energy development technology which included exploration, development, production, distribution, storage and utilization of energy and new forms of energy. Also, an appraisal was made of recent resource recovery and research and development of energy conversion technology, distribution, and utilization (Over)

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efficiency. The economic aspects of energy developments and use were discussed as related to patterns of consumption, trade, and the Gross National Product of the Soviet Union and Eastern European countries. The overall energy supply and demands of these countries were projected to the 1980 and 1990 time frames. Finally an analysis was made of the Soviet political/military/energy strategy policies relative to the economic impact on Eastern and Western Europe.

This appendix will briefly cover the electric industry of each of the Eastern European Soviet satellite countries and discuss in more detail this industry in the Soviet Union.

ANALYSIS OF ENERGY RESOURCES AND
PROGRAMS OF THE SOVIET UNION AND EASTERN EUROPE

Appendix F: Electric Power

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I OVERVIEW

A. Introduction

Since electric power generation is the single largest consumer of fuels/energy resources in eastern Europe, it is important to examine this industry, giving consideration to the following:

- Historical growth of electric power generation.
- The fuels and energy supply base and historical changes in this base.
- The efficiency of utilization of fuels and energy in the electric power industry.
- Present and future technology as it relates to production of electric power.
- Effects of this industry as they relate to:
  - Projected strains on the fuels/energy resources of the COMECON Bloc.
  - Energy trade of the COMECON Bloc.
  - Implications regarding possible trade in energy with Western countries.

This appendix will cover the first four points, while the last point and a more detailed discussion of the resources base will be covered in Appendix A.

Brief coverage will be given of the electric industry of each of the eastern European Soviet satellites (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania). A more detailed discussion will be given to this industry in the USSR because of its predominant importance, in relation to fuel supplies and technology, to the Eastern Bloc.

B. Summary and Conclusions

To sustain the projected industrial growth rates, the demands for fuels/energy resources by the Eastern European countries will grow appreciably in the next 20 years. Electric power stations account for up to 30 percent of all fuels/energy resources consumed in the COMECON bloc, and thus, should put a definite strain on the ability of these countries to invest capital and manpower in order to obtain the required energy.

Only Poland, besides the USSR is in position to satisfy its full demands for electric power from internal sources for the near term. Even Romania, which is the only other country not depending on imports for its energy at present, will be looking for outside sources if its industrial growth is to be sustained in the future. The following are the main conclusions that can be reached in regard to the fuels/energy supplies to COMECON countries:

- Very heavy reliance on imports of Soviet oil and gas for future expansion of thermal power plant capacities.
- The possibility of sizable imports of oil and gas from the Middle East* because of possible inability of the USSR to supply the projected demands for oil and gas.
- Ever-growing reliance on the exchanges of power among the COMECON members through further development of the common, integrated "MIR" power grid system.

The technical development of the electric power industry will probably proceed on the following lines:

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* The possibility of Middle East oil imports by satellite countries has been cropping up in Soviet literature, leading one to speculate that such imports are being considered as a serious alternative, or at least as a supplement to Soviet oil.

- Fairly rapid development of nuclear power in East Germany, Bulgaria, and Czechoslovakia after 1980, based on Soviet technology.
- Further large growth in hydroelectric installations in the USSR. Some significant development of hydroelectric capacity in Romania, at least through 1980.
- For other Eastern European countries, no scheduling of sizable hydroelectric projects for the future.
- Rapid introduction of modern thermal power technology, such as 500 MW turbogenerators working on supercritical and subcritical steam. The USSR will remain the basic supplier of this equipment.
- No introduction of MHD type technology until at least 1985.
- Expansion of long-distance transmission of electric power within the USSR, by tying in the Siberian and European Russian grids.
- Expansion of high-voltage transmission lines within the COMECON bloc.

C. Hydroelectric Energy in the USSR and Eastern Europe

Hydroelectric energy is created by the flow of water between different elevations.* This energy is used to drive turbines which in turn drive generators that convert the mechanical energy into electricity. Although simple in concept, hydroelectric energy is a complex enterprise in practice. Stream flows typically vary over the short term (and long term as well), reflecting patterns of rainfall and runoff that are beyond control. Short term fluctuations in stream flow may be mitigated by use of storage reservoirs, but this approach is less effective in dealing with longer term water shortages. A further complication is that water developments are frequently designed for

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* This is the concept of "head" often used in engineering discussions of hydroelectric energy.

multiple uses. Stored water may also be used for irrigation or maintenance of navigation channels, and not all may be available for power production. Power generation, irrigation, and navigation may be incompatible with flood control, which requires relatively low reservoir levels to accommodate expected water volumes from flooding.

The physical basis for hydroelectric energy is the quantity of water descending a vertical distance (or flowing past a given point). The maximum hydroelectric potential of a country is therefore the total quantity of water flowing in its streams and the vertical distance it descends. This concept of total flow multiplied by head is the "theoretical hydroelectric potential," and is commonly stated in kilowatts (kW) or kilowatt-hours (kWh). The theoretical potential can never be achieved; it represents an upper limit that can only be approached. Thus, the "technical potential" of hydroelectric energy is employed to describe resources that can be developed within available technical capabilities, allowing for losses inherent in any such conversion system. These concepts are therefore the equivalent to those of the "original resource base" and "remaining resources" of the fossil fuels. Of course, not all the technical potential will be realized, mainly because of economic factors; there is thus an "economic potential" that further limits the developable hydroelectric energy. This latter category is comparable to the "recoverable reserves" of the fuels.

Table F-1 summarizes the theoretical hydroelectric potentials of the Eastern European countries, as determined by the United Nations Economic Commission for Europe. The largest gross (theoretical) potential is for the USSR's Asiatic part, which alone dwarfs all the other countries combined. As noted above, however, the theoretical potential is greatly in excess of what can be economically developed. Table F-2, also from the Economic Commission for Europe, shows technically exploitable hydro resources as well as economically usable

Table F-1

SUMMARY OF HYDROELECTRIC POTENTIALS OF THE USSR AND EASTERN EUROPEAN COUNTRIES

Country	Area (thousand km^2)	Approximate Mean Water Supply from Precipitation (mm)	Approximate Mean Annual Runoff (mm)	Gross Surface Hydroelectric Potential from Mean Annual Runoff: Billion kWh	Gross Surface Hydroelectric Potential from Mean Annual Runoff: Million kWh/km^2	Gross Surface Hydroelectric Potential from Mean Annual Runoff: Thousand kWh per Inhabitant	Technically Exploitable Hydro Resources (billion kWh)
Bulgaria	111	670	160	35	0.32	4.76	15.8
Czechoslovakia	128	720	220	41	0.32	2.89	12.0
E. Germany	108	600	150	16	0.15	0.94	20.6
Hungary	93	640	70	12	0.13	1.18	3.4
Poland	313	580	160	32	0.10	1.07	12.1
Romania	238	780	190	85	0.36	4.46	23.4
USSR*	5,560	570	195	972	0.17	5.53	314.0

* European USSR, including Caucasus.

Source: United Nations Economic Commission for Europe, "The Hydro-electric Potential of Europe's Water Resources, Vol. 1, Methods of Analysis and Their Application," 1968.

Table F-2

EASTERN EUROPEAN HYDROELECTRIC POTENTIALS
(Billion kWh)

Country	Gross Potential (Theoretical)	Technically Exploitable Potential	Economically Usable Potential
Bulgaria	35	15.8	10.2
Czechoslovakia	41	12.0	8.2*
East Germany	16	2.0	< 1.0†
Hungary	12	3.4	< 2.4*
Poland	32	12.1	6.0
Romania	85	23.4	17.0*
USSR	~ 5,500‡	2,160	1,100
Total	5,721	2,228.7	1,144.8

---

* Calculated from technically exploitable potential based on UN-determined factor that economically exploitable potential is about 20 percent of gross potential.

† Calculation from gross potential yields value greater than technically exploitable potential; economic potential assumed to be roughly half of technical potential.

‡ Back-calculated from economic potential using above factor.

Source: United Nations Economic Commission for Europe, "The Hydroelectric Potential of Europe's Water Resources, Vol. 1, Methods of Analysis and Their Application," 1968.

hydro resources are only about 20 percent of the gross theoretical potential. All but 4 percent of the economically usable hydro potential occurs in the USSR. Outside the USSR, the largest potentials are for Romania and Bulgaria as a result of their mountainous terrain and well-established drainage system.

II ELECTRIC POWER IN THE USSR

The electric power industry has always enjoyed a privileged position in the planned economic growth of the USSR. Being the largest single user of fuel of all the economic sectors, consuming about 32 percent of all the available fuel* in 1970, it warrants a special attention in assessment of its potential for growth, particularly as it relates to factors affecting the economic use of fuels.

In the following sections, a general coverage of the historical, present, and future state of the electric power industry of the USSR will be given. The sections will cover the generation of electric power by hydroelectric, thermal, and nuclear power stations, with particular emphasis on the way these play a role in the fuels/energy balance of the country.

A. Historical Growth

The original basis for the development of the electric power industry of the USSR was laid down in the document adopted by the Eighth All Russian Congress of the Soviets in December 1920. The plan, called "GOELRO" (the State Commission for Electrification of Russia), was one of the primary goals of the Soviet regime for laying a foundation for industrialization and was strongly sponsored by Lenin, who considered implementation of the plan as fundamental to the success of Communism. Even now, although not all the goals of the original plan have been

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* In all the discussions regarding fuel use in electric power stations, all fuels will be related to the standard coal equivalent fuel that is defined as having a heat content of 7,000 Kcal/kg (12,600 Btu/pound).

adhered to, it is used as an example of a rational approach to the development of an industrial power base.

The plan included:

1. The construction of large regional electric stations based on locally available fuel resources.
2. The development of hydroelectric resources with a view toward not only providing electric power but also fostering water transport and irrigation.
3. A rational distribution of electric power production over the country.
4. The building of an integrated transmission grid.[1]

In its essentials, this plan was completed in 1931. The plan was intended to be implemented in a period of 10 to 15 years. If we leave out the period of the revolution and that of the civil war and compare the total installed electric power capacity in 1932 to that in 1922, we see an average annual growth rate of 14.1 percent. Some of this growth should be attributed to reconstruction of existing facilities laid waste by civil upheavals. The dynamics of growth of installed electric power capacity can be seen in Figure F-1. This average growth rate was not sustained in later periods; however, with the exception of the war period, 1940-1945, it was nevertheless very impressive. The average annual growth rate was 11.9 percent in the period of 1955 to 1965 and dropped to 7.6 percent during the eighth five-year plan, 1966 through 1970.

The dynamics of installed capacity and electric power production are given in Tables F-3 and F-4, respectively.

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1 "Energeticheskaiya, atomnaiya, transportnaiya i aviatsionnaiya tekhnika kosmonotika" (Electric, atomic, transport, aviation, and space technology), Nauka, I. I. Artobolevskii, ed., pp. 16-18 (Moscow, 1969).

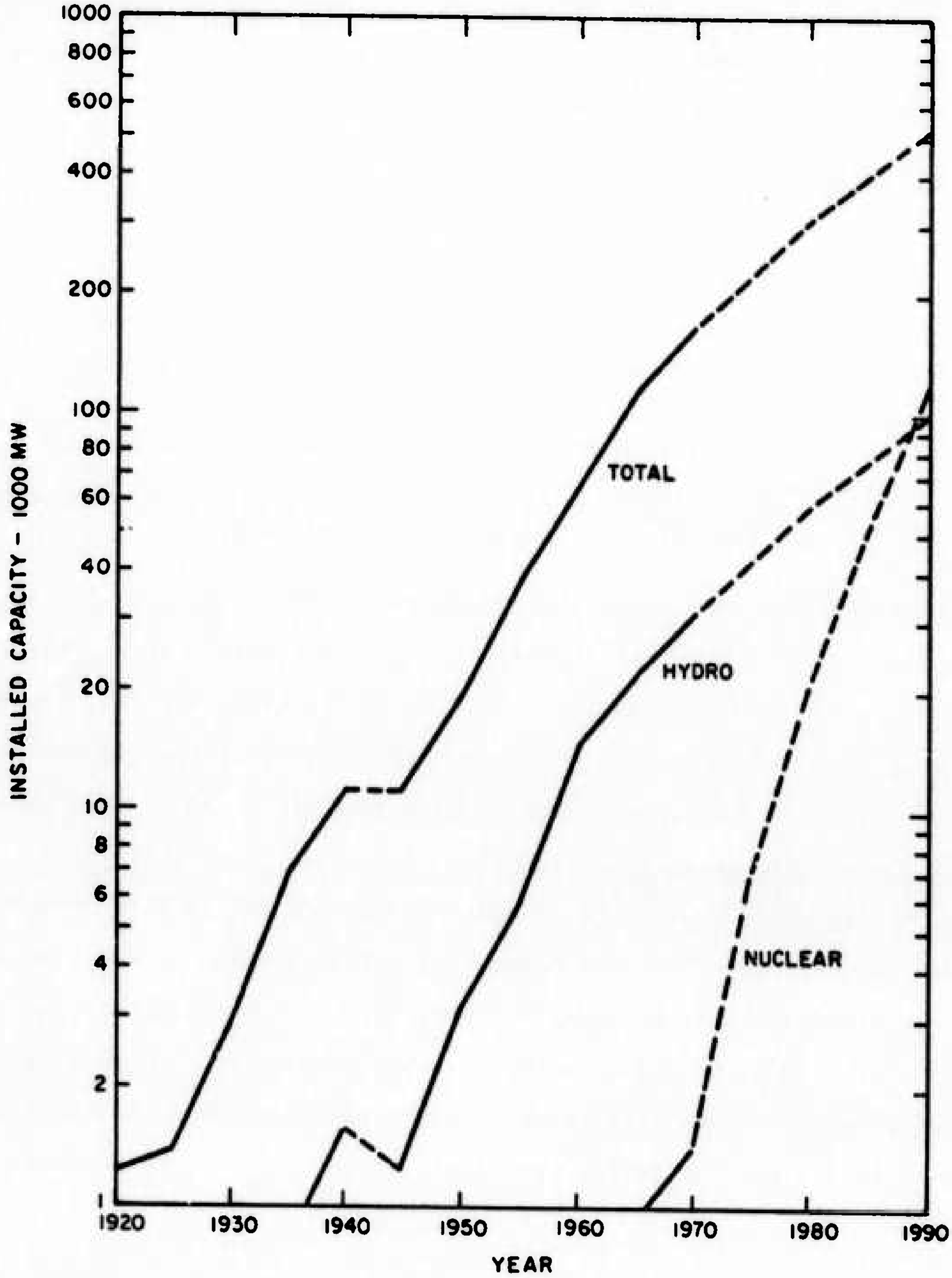

Figure F-1

INSTALLED ELECTRIC POWER CAPACITY IN THE USSR

Table F-3

INSTALLED CAPACITY OF ELECTRIC POWER GENERATORS IN THE USSR, BY TYPE[*]
(1000 MW)

	Thermal Stations						
	Steam Turbines						
Year	Condensing	Heat and Power	Others[†]	Total Thermal[‡]	Hydroelectric	Nuclear[§]	Total
1950				16.4	3.2	-	19.6
1955				31.2	6.0	-	37.2
1956				35.0	8.5	-	43.5
1957				38.4	10.0	-	48.4
1958	20.9[■]	13.0[■]	8.7	42.6	10.9	0.1	53.6
1959				46.5	12.7	0.1	59.3
1960				51.8	14.8	0.1	66.7
1961				57.6	16.4	0.1	74.1
1962				63.8	18.6	0.1	82.5
1963				72.0	21.0	0.1	93.1
1964				81.4	21.3	0.9	103.6
1965	48.2[•]	32.7[•]	11.0	91.9	22.2	0.9	115.0
1966				99.0	23.1	0.9	123.0
1967				105.7	24.8	1.2	131.7
1968				114.3	27.0	1.2	142.5
1969				122.8	29.6	1.4	153.8
1970	76.2[••]	47.0[•]	10.2	133.4	31.4	1.4	166.2
1971				140.1	33.4	1.9[††]	175.4
Plan 1975	99.5[•]	65.0[•]	12.5-14.5	177-179[‡‡]	43[‡‡]	6-8[‡‡]-7.1[††]	228[‡‡]
1980					59[††]	21[††]	
Plan 1982	155[••]						350[••]
1985						53[††]	
1990					100[††]	118[††]	

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[*] Unless otherwise indicated, all data are from Soviet statistical annuals *Narodnoie Khoziaistvo* (National Economy).

[†] Internal combustion engines and gas turbines.

[‡] By difference: Total minus (Hydroelectric + Nuclear).

[§] From U.S. Atomic Energy Commission, *Soviet Power Reactors-1970*, Washington, D.C., 1970, p. 8.

[■] *Electrifikatsia SSSR* (Electrification of the USSR), Moscow 1970, p. 59.

[•] *Energetika SSSR v 1971-1975 Godakh* (Energetics of the USSR in 1971-1975), Moscow, 1972, pp. 108, 110.

[••] Ibid., p. 75.

[††] SRI estimate.

[‡‡] Official Soviet five-year plan.

Table F-4

GENERATION OF ELECTRIC POWER AND HEAT BY ELECTRIC STATIONS IN THE USSR
(Billion kWh)*

	Thermal Stations								
	Electricity				Heat† (million gigacalories)				
Year	Condensing Turbines	Heat and Power Turbines	Others	Total‡	Total	Public Stations	Hydroelectric	Nuclear	Total
1950				78.535		28	12.691	-	91.226
1955				147.060		63	23.165	-	170.225
1956				162.669		76	28.984	-	191.653
1957				170.259		90	39.429	-	209.688
1958				188.872		109	46.478	-	235.350
1959				217.482		124	47.630	-	265.112
1960				241.361	212	145	50.913	-	292.274
1961				268.489		171	59.122	-	327.611
1962				297.331		191	71.944	-	369.275
1963				336.559			75.859	-	412.418
1964				381.541			77.361	-	458.902
1965		174.5§		425.238	465**	308**	81.434	-	506.672
1966				451.096			91.823	1.647	544.566
1967				497.328			88.571	1.800	587.699
1968				532.121			104.040	2.500	638.661
1969				570.969		470††	115.181	2.900	689.050
1970		177.8§		613.049	699**	507**	124.377	3.500	740.926
1971				669.761			126.099	4.500	800.360
Plan 1975				875‡‡	970‡‡	760**	185‡‡	25‡‡	1065‡‡
1980								95§§	
1985								255§§	
1990								670§§	

* Unless otherwise indicated, all data are from the USSR statistical annuals *Narodnoie Khozieistvo* (National Economy) and *Promyshlennost SSSR*.

† From heat and power turbines.

‡ By difference: Total minus (Hydroelectric + Nuclear).

§ SRI estimate based on statements in N. V. Melnikov, *Mineralnoe toplivo* (Mineral Fuels), Pub. "Nedra," Moscow 1971, pp. 185-186.

** Energetika SSSR v 1972-1975 Godakh, pp. 81, 102.

†† Doroshchuk, V. E. Mkhitaryan, "Present State and Future Development of the Thermal Power Industry in the RSFSR," Combustion, May 1973, p. 40.

‡‡ Official Soviet five-year plan.

§§ SRI estimate.

B. <u>Hydroelectric Power Stations</u>

Hydroelectric power has played a glamorous role in the growth of the electric industry in the USSR, perhaps to the detriment of economic benefits to be derived from it, particularly in later years. The early emphasis on its development had rational roots in the goals that the new Soviet government set for itself after the end of the civil war. The intent to rapidly industrialize demanded large amounts of electricity. However, it also required large amounts of foreign exchange for purchases of industrial machinery, which could most easily be obtained by exporting oil. Coal, oil, and wood constituted the main sources of fuel at that time, with oil accounting for about 30 percent of all the fuel production. It was obvious that coal production and transport could not be expanded rapidly enough to carry the load of providing all the required power and that the use of wood resources would have been insufficient and technically and economically undesirable. The choice of using local regional resources, such as easily obtainable low grades of coal, peat, shale, and particularly water resources, was obvious.

1. <u>Location of Hydroelectric Complexes</u>

The USSR is endowed with large water resources, however unevenly they might be distributed throughout the country. Most of these are located in Siberia and are yet to be tapped. It has been estimated by the Soviets that as of January 1969, 10 percent of the economically developable water resources of the country have been utilized. With the completion of the current construction projects, this proportion would rise to 17.5 percent.

These numbers, however, do not reflect the potential for hydroelectric development in the near future. If we look at the distribution of the developed sites, it becomes obvious that the extent of

development in the most populated and industrialized areas is well advanced (Figure F-2).

The present approach to the development of this resource is based on economic planning, which takes into account the interest on the capital requirements of this highly capital intensive industry. The locations of hydroelectric stations will be limited to those areas where local fossil fuel resources are inadequate or their transport costs are prohibitive. The momentum generated in the early years in building hydroelectric facilities had carried into the time when building of some of these facilities was economically unjustified in comparison to the thermal stations. The location of major existing and future hydroelectric stations is shown on the attached map.

2. Installed Capacity and Sizes of Hydroelectric Stations

The installed capacities of Soviet hydroelectric facilities tend to be very large. As of the end of 1970, the total installed hydroelectric capacity was 31.4 million kW, representing approximately 154 stations (Table F-5). They were broken down by sizes as follows:

Hydroelectric Station Installed Capacity[5]
(Megawatts)

	5.1-25	25.1-100	101-300	300-1,000	Greater Than 1,000
Number of stations	52	54	27	16	5
Installed capacity (million kW)	0.6	2.8	4.5	8.2	15.2

There were five stations with individual capacities of well over 1,000 MW.

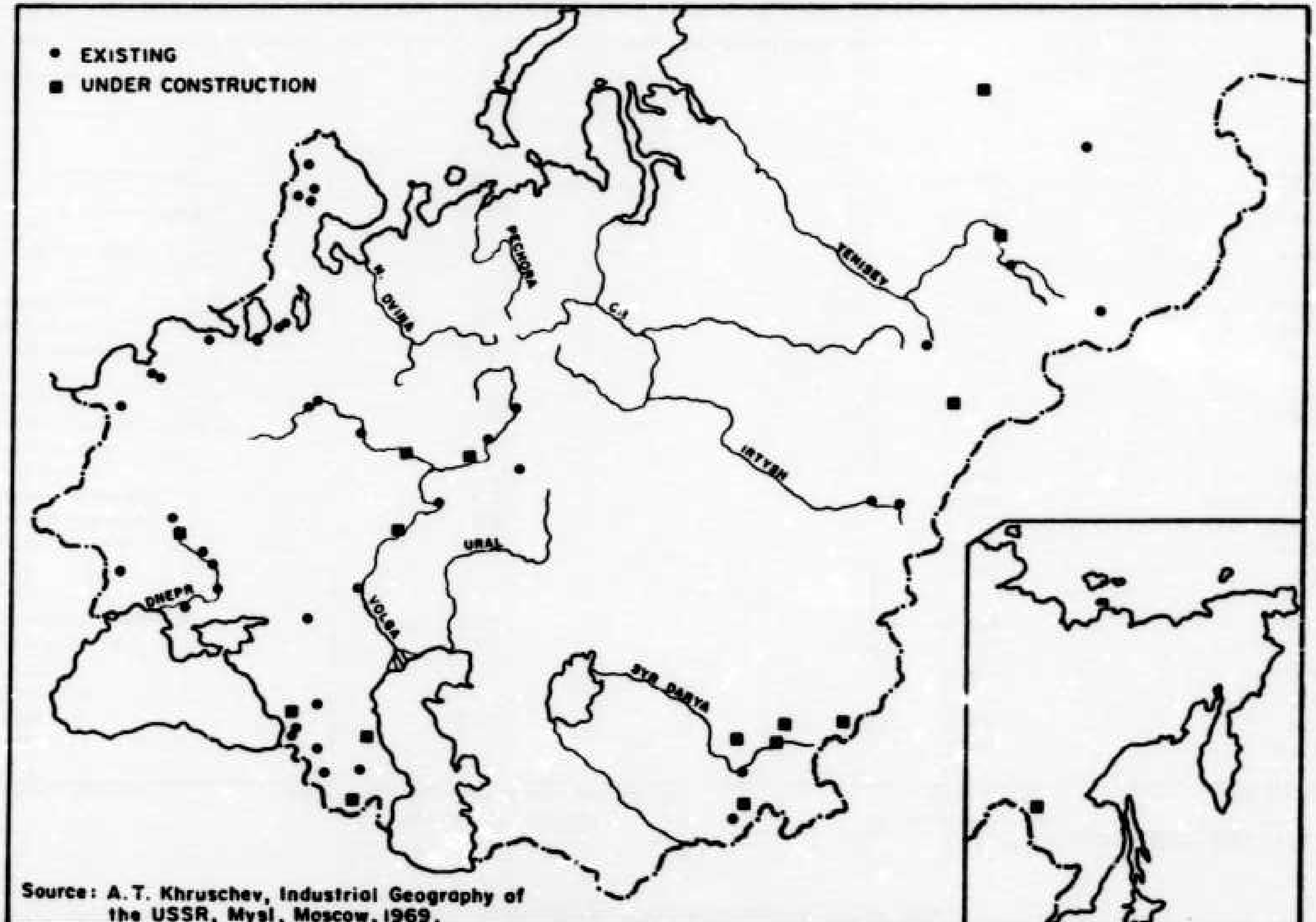

Figure F-2

MAJOR HYDROELECTRIC STATIONS IN THE USSR

Table F-5

HYDROELECTRIC POWER UTILIZATION IN THE USSR

Economic Region	Installed Capacity* (% of economically usable potential)	Production of Hydroelectricity: Production in 1970 (million kWh)	Production of Hydroelectricity: % of Total Production of Electricity
1. North West		9,499	36.3%
11. Baltic	25.0	2,136	9.7
12. Belorussia		28	0.2
2. Central		2,690	2.8
3. Volga-Viyatskii			
4. Central-Chernozemnii	50.2	28,129	35.6
5. Volga			
7. Urals		4,590	5.8
6. North Caucasus	8.4	3,128	10.9
8. Western Siberia	4.2	2,140	6.6
9. Eastern Siberia	9.1	42,242	63.5
10. Far East	0.4	637	5.3
13. South Western			
14. Donetsko-Pridneprovskii	51.6	11,851	8.7
15. Southern			
M. Moldavia			
16. Transcaucasus	12.7	4,696	17.9
17. Kazakhstan	6.6	5,021	16.4
18. Central Asia		6,413	24.8
Total USSR	10.0	123,200†	18.2
European USSR	30.7	66,747	13.2
Asiatic USSR	5.1	56,453	33.6

* As of January 1969.

† This was a preliminary estimate. The official final figure was 124,377 million kWh.

Sources: For installed capacity, Soviet statistical annuals Narodnoie khoziaistvo (National Economy); for production, Energetika SSSR v 1971-1975 Godakh.

3. Construction Periods and Costs

The period for construction of hydroelectric projects is in general much longer than that for thermal stations. On the average, the reported time span for site preparation, before actual construction begins, takes two to three years.[2] This includes, among other things, construction of roads, living facilities, electric transmission lines, sites for production of materials, warehousing, etc. The actual construction time may vary from five to seven years, or in some cases much longer. Table F-6 presents examples of reported construction periods and costs of some of these installations.

In view of the length of time and the heavy capital expenditures required for the development of hydroelectric resources, they are not likely to sustain the rapid growth rate experienced in the immediate post-war period. This decision seems to have been made during the construction of the seven-year plan (1959-1965).[3]

The reported costs of construction of hydroelectric facilities have been going down since the post-war period. These were about 470 rubles/kW installed capacity in 1952-1957 and had dropped to about 160 rubles/kW in the 1959-1965 period.[4] These large differences were mainly due to the inefficiencies in the industry during the reconstruction period after World War II, lack of equipment, material, and trained manpower. The growth of the average size of installed units contributed to further reductions as well.

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[2] Energeticheskoe stroitelstvo, No. 10-11, p. 94 (1971).

[3] A Report on Electric Power Development in the USSR, p. 13 (Edison Electric Institute, New York, N.Y., 1963).

[4] A Report on Electric Power Development in the USSR, p. 19 (Edison Electric Institute, New York, N.Y., 1963).

Table F-6

CONSTRUCTION PERIOD AND COSTS
FOR SOME REPRESENTATIVE HYDROELECTRIC STATIONS IN THE USSR

Station	River	Power (million kW)	Construction* Period	Reported Cost* (million rubles)
Kamskaiya	Kama	0.50	1950-1956	150
Gorkovskaiya	Volga	0.52	1950-1956	187
Charvakskaiya	Chirchik	0.60	1963-1967	62
Irkutskaiya	Angara	0.66	1950-1956	94
Pliyvinskaiya	Daugava	0.83	1961-1966	49
Chirkeiskaiya	Sulak	1.00	1963-1967	36
Volzhskaiya-Lenin	Volga	2.30	1950-1957	701
Nurekskaiya	Vakhsh	2.70	1963-1967	118
Bratskaiya	Angara	4.10	1955-1962	532
Krasnoyarskaiya	Enisei	5.00	1955-1968	491

* Excluding site preparation.

Source: Energeticheskoe stroitelstvo, No. 10-11, 1971, p. 96.

Our estimated present cost of construction is about 110 rubles/kW installed power for an average station size of 1,000 MW. This cost would imply an investment of approximately 1.25 billion rubles for the planned construction during the 1971-1975 five-year plan. This amount represents 7 percent of all the capital investment slated for the power industry in this period. The estimated costs include an allowance for the expected further drop in the construction costs for this planning period. These costs, however, are expected to rise beyond 1975,

when new remote sites are to be exploited on the Enisei and Angara Rivers. (Table F-7 presents a list of the most important hydroelectric river systems in the USSR.)

4. Uses of Hydroelectric Installations

Much of the power for peak load periods is supplied by hydroelectric stations. At present, the expansion of some of the facilities are intended for this specific use. The first pumped storage facility in the USSR is being constructed at the Kiev station on the Dnepr River and construction of another one is scheduled to begin before 1975 at Zagorsk. These installations are primarily intended for peak loads.

The other important multiple uses for hydroelectric facilities are navigation and irrigation. Most of the dams and facilities installed in central Asia and Kazakh SSR are partly justified by the planners for irrigation, while those in the European area are used for navigation as well.

It is expected that the growth in hydroelectricity will not be sufficient in the future to supply all the peak capacity that is necessary. The slack is expected to be picked up by gas turbine installations. These are intended to be installed at the hydroelectric sites.

5. Present State of Hydroelectric Technology

The achievements of the USSR in the field of hydroelectric power technology have become well-known with the worldwide publicity given to the construction of the Aswan Dam in Egypt.

Production of turbines and generators has reached a stage where they are competitive and technically as advanced as any available on the world markets. Even shortly after the war, when the United States helped with the reconstruction of the Dneproges by providing the Soviets

Table F-7

MOST IMPORTANT HYDROELECTRIC RIVER SYSTEMS IN THE USSR
(As of January 1, 1970)

River System	Station Site	Potential Capacity (MW)	Potential Annual Power Generation (kWh × 10^9)	Number of Units and Installed Capacity (MW)* Operational	Under Construction	Site in Preparation	Possible Expansion
Enisei	1. Saiyanskaiya	6,400	23.5		8x640=5,120		2x640=1,280
	2. Mainskaiya	320	1.6				320
	3. Ochurskaiya	400	1.6				400
	4. Mimusinskaiya	450	2.2				450
	5. Krasnoyarskaiya	6,000	20.4	10x500=5,000			2x500=1,000
	6. Sredne-Eniseiskaiya	6,400	35.7			6,400	
	7. Osinovskaiya	6,100	30.2				6,100
	8. Igarskaiya	5,000	30.6				5,000
Angara	1. Irkutskaiya	660	4.1	8x62.5= 660			
	2. Bratskaiya	4,600	22.4	16x225+2x250=4,100			2x250= 500
	3. Ust-Ilimskaiya	4,320	21.9		3,600		720
	4. Boguchanskaiya	4,000	19.0			4,000	
Volga	1. Ivankovskaiya	30	0.13	2x15= 30			
	2. Uglichskaiya	110	0.24	2x55= 110			
	3. Rybinskaiya	330	1.1	6x55= 330			
	4. Gorkovskaiya	520	1.51	8x65= 520			
	5. Cheboksarskaiya	1,400	3.53		32x44=1,400		
	6. Volzhskaiya-Lenin	2,300	10.9	20x115=2,300			
	7. Perevolokskaiya	2,400	2.0			1,600	600
	8. Saratovskaiya	1,290	4.5	21x57+2x45=1,290			
	9. Volzhskaiya-KPSS	2,530	11.1	22x115=2,530			
	10. Nizhne-Volzhskaiya	1,530	6.4				1,530
Kama	1. Verkhne-Kamskaiya	630	2.07			630	
	2. Kamskaiya	504	1.92	24x21= 504			
	3. Votkinskaiya	1,000	2.39	10x100=1,000			
	4. Nizhne-Kamskaiya	1,080	2.85		1,080		
Dnepr	1. Kievskaiya	350	0.635	20x17.5= 350			
	2. Kanevskaiya	420	0.823		24x17.5= 420		
	3. Kremechuzskaiya	625	1.506	12x52.1= 625			
	4. Dneprodzerzhinskaiya	352	1.26	8x43.8= 352			
	5. Dneprovskaiya-Lenin	1,476	4.14	9x72.2= 650		8x103.5= 828	
	6. Kakhovskaiya	351	1.42	6x58.5= 351			

Table F-7 (Concluded)

River System	Station Site	Potential Capacity (MW)	Potential Annual Power Generation (kWh × 10^9)	Number of Units and Installed Capacity (MW)* Operational	Under Construction	Site in Preparation	Possible Expansion
Chirchik-Bozsuiskiy	1. Charvakskaiya	600	2.0		4x150 0= 600		
	2. Khodzhikentskaiya	165	0.56			3x55 0= 165	
	3. Gazalkentskaiya	80	0.40			3x26.7= 80	
	4. Tavakskaiya	72.8	0.325	4x18 2= 72.8			
	5. Chirchikskaiya	86.4	0.394	4x21.6= 86.4			
	6. Akkavakskaiya I	36.8	0.232	36.8			
	7. Akkavakskaiya II	9.0	0.66	9.0			
	8. Akkavakskaiya III	11.0	0.89	11.0			
	9. Kadyrinskaiya	13.2	0.122	13.2			
	10. Salarskaiya	11.7	0.085	11.7			
	11. Bozsuiskaiya	4.0	0.028	4.0			
	12. Sheikhantaurskaiya	3.6	0.029	3.6			
	13. Burdzharskaiya	6.6	0.040	6.6			
	14. Aktepinskaiya	15.0	0.082	15.0			
	15. Nizhne-Bozsuiskaiya I	10.7	0.041	10.7			
	16. Nizhne-Bozsuiskaiya II	7.2	0.031	7.2			
	17. Nizhne-Bozsuiskaiya III	12.8	0.051	12.8			
	18. Nizhne-Bozsuiskaiya IV	18.4	0.099	18.4			
	19. Nizhne-Bozsuiskaiya V	1.6	0.030	1.6			
Vakhsh	6 stations	6.658		3 st† = 258	1 st=2,700	1 st=3,200	1 st= 500
Naryn	13 stations	4.176		4 st = 524	1 st=1.200	1 st= 500	7 st=2.252
Irtyan	6 stations	3.279		2 st =1,007		1 st=1.200	3 st=1.072
Inguri	3 stations	2.850			1 st=1,640	1 st= 850	1 st= 360
Kura	8 stations	1.371		5 st = 463		1 st= 350	2 st= 558
Sulak	4 stations	1,301		2 st = 81	1 st=1.000	1 st= 220	
Sevana	6 stations	556		6 st = 556			
Voroten	3 stations	407		1 st = 157	2 st= 247		
Vyga	5 stations	234		5 st = 234			
Khrami	2 stations	225		2 st = 225			
Pas	5 stations	185		5 st = 185			
Total		87,321		71 st =25,600	13 st=21,370	12 st=20,41[illegible]	

* The first number indicates numbers of generating units; the second indicates power (i.e., 8x640 means 8 units of 640 MW each).

† Number of stations.

Source: Elektrifikatsea SSSR. Pub. "Energia," Moscow 1970, pp. 245-250.

with three turbines and generators build by Newport News Shipbuilding and Dry Dock Company and by General Electric Company, similar Russian turbines were installed side by side. They turned out to be as efficient and reliable as the ones of U.S. manufacture.

One of the biggest turbines in the world was installed in 1963 at the Krasnoyarsk station. It is a Francis type turbine rated at 508 MW at 93.8 rpm at a working head of 100 meters. It generates a voltage of 15.75 kV. Similar turbines are now being built for the Nurekskiy station, on the River Vakhsh, as well as for export. They have a capacity of 300 MW at 230 meters head. The unique features of the associated generators are that the stators are internally water cooled and the rotors are forced air cooled. Investigations are going on into feasibility of water cooling the rotors as well.

Kaplan type turbines of 115 MW have been produced for such stations as the Volzhskaiya-Lenin. This station has 20 of these turbines installed.

Special units, such as the encapsulated turbine-generators, have been produced as well. A horizontal unit of this type was built for the Kievskiy station. Its installed capacity is rated at 18.5 MW at 85.7 rpm. The voltage output of the generator is 3.15 kV.

Construction of arch and arch-gravity dams has been mastered in the last few years. An example of an arch dam is the one being constructed at the Chirkeisk station on the River Sulak. Some of the others, such as the Ingurskaiya (Inguri River), are being built with a total head of 271 meters. The Toktogul dam (Naryn River) is to be an arch-gravity dam of 215 meters head. These are the first of their kind to be built in the USSR.

It is obvious from the above examples that the USSR technical capabilities in construction of hydro projects is at least as advanced as some of the best projects in the United States or Western Europe.

6. Future Growth of Hydroelectricity

Twenty-five stations were under construction at the beginning of 1970, with a planned installed capacity of 22 million kW. Of these, 11.4 million kW were expected to be installed in the period 1971 through 1975, of which 11.3 million kW are to be from projects started before 1971 and about 0.1 million kW from projects begun in the current five-year plan. The planned installed capacity by the end of 1975 is to be 43 million kW and the corresponding production of electricity from these stations is to be 165 billion kWh. It is our estimate that these goals are likely to be met.

For the longer time span, it is expected that the present ratio of the installed capacity of hydroelectric stations to that of all electric stations (including nuclear) will stay the same. With a probable annual growth rate of 6.5 percent through 1980 and 5.5 percent through 1990 for all electric power, it is expected that the hydroelectric installed power capacity will be 43,000 MW in 1975, 59,000 MW in 1980, and 100,000 MW in 1990.

C. Thermal Power Stations

Thermal power stations represented 80 percent of the total installed electric generating capacity of the USSR in 1970. These stations produced about 82.7 percent of all the electric power for that year.

An important segment of the thermal power stations in the USSR is the so-called "district-heat" stations (TETS). They supply both electric power and steam/hot water to the consumers. They represent, at present,

over one-third of all steam and hot water supplied to the economy. The 1970 and 1975 shares of thermal power station production of heat in all heat generation in the USSR is presented in Figure F-3 and F-4, respectively. In terms of power generating capacity, they represented over 35 percent in 1970. Their share in total thermal station electric generating capacity is likely to remain the same (40 percent of all steam turbine units).

The other thermal power stations are represented by the condensing turbine, large base-load units (GRES). These have been steadily growing in size and technical performance in order to lower both the installed costs and fuel consumption.

Figure F-5 shows the location of major thermal power stations in the USSR.

1. Station Sizes and Steam Parameters of Thermal Stations

The station sizes and individual turbogenerator sizes making up the station complement have been growing in the USSR at an appreciable rate in the last 20 years. Whereas the maximum station size of the condensing turbine plant (GRES) in 1950 was 510 MW, in 1970 it was 2,440 MW and is expected to be 3,000 MW in 1975. For the combined electricity-heat plants (TETS), they were 150 MW and 600 MW, respectively, and are expected to grow to a maximum size of 1000 MW by the end of 1975. The growth patterns for the maximum sizes of stations and individual turbogenerators as well as the steam parameters can be seen in Table F-8. The breakdown of all installed steam-turbine thermal station capacity by turbogenerator sizes is shown in Table F-9.

At present, at least one station is reported to operate with individual turbogenerator size of 800 MW in the supercritical region. The steam parameters, however, are not as high as those in the United States. The maximum inlet steam condition used in the USSR is 3,413 psi

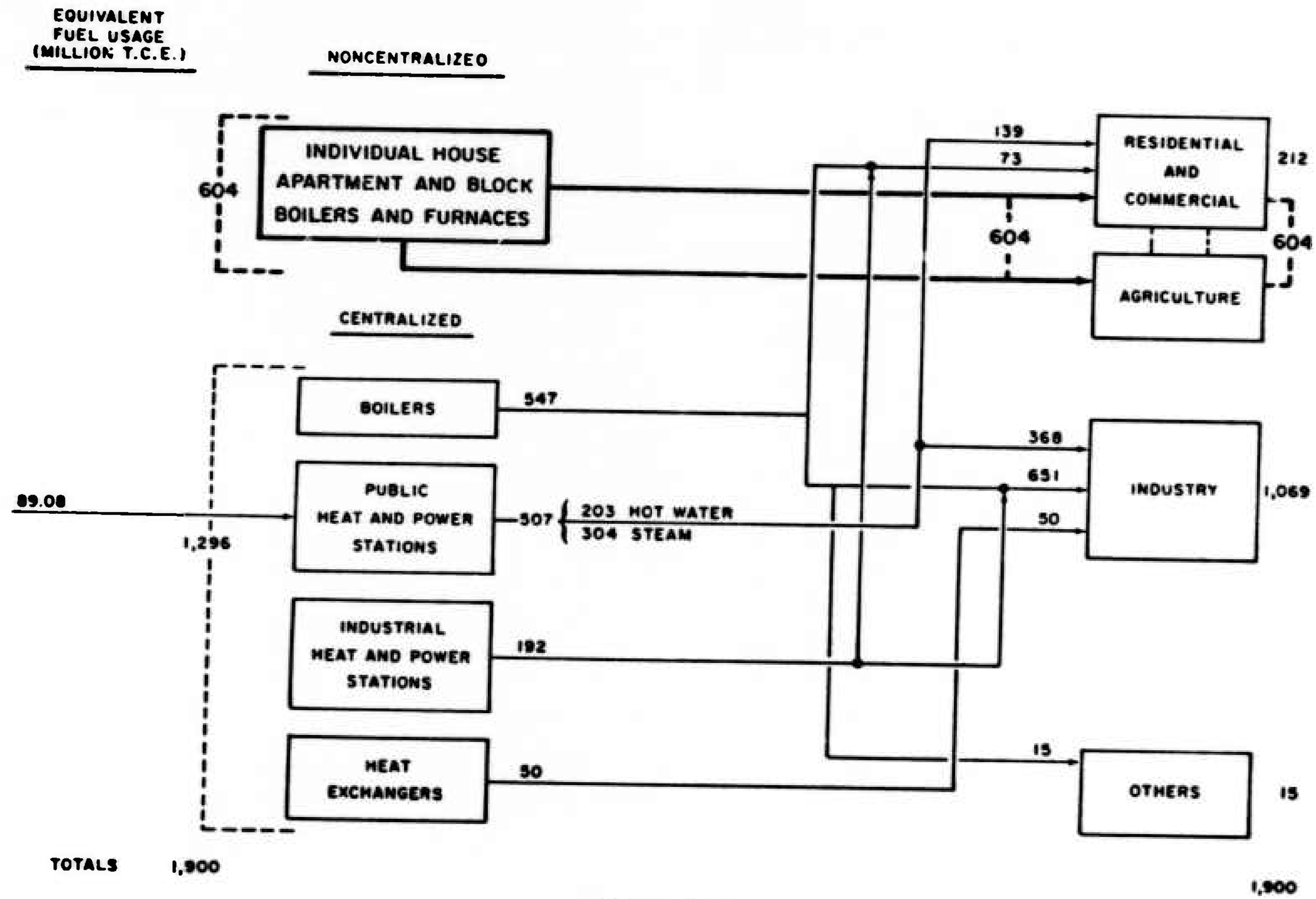

Figure F-3

STEAM AND HOT WATER USE IN THE USSR – 1970

(Million Gigacalories)

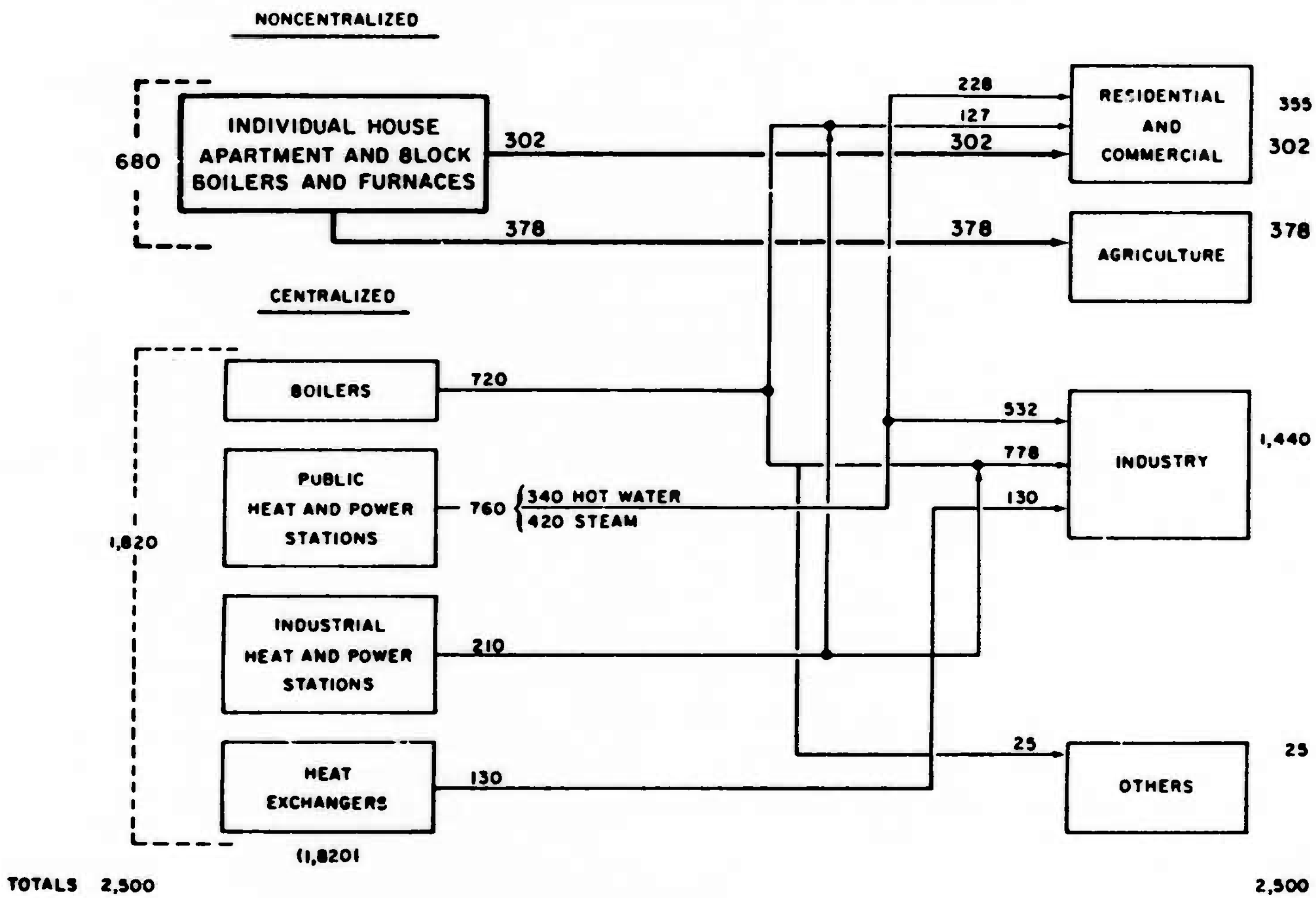

Figure F-4

STEAM AND HOT WATER USE IN THE USSR - 1975 (PLAN)

(Million Gigacalories)

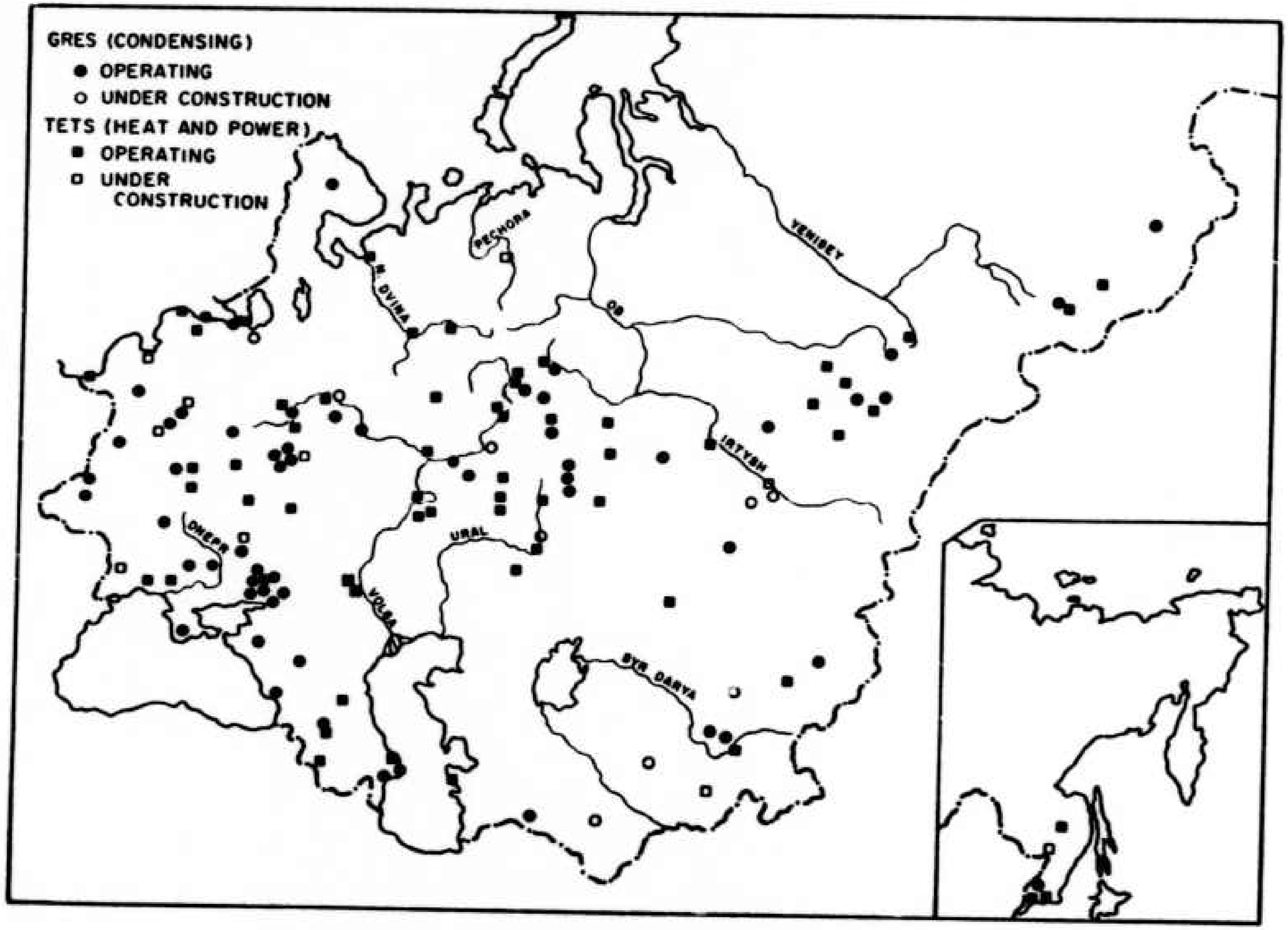

Figure F-5

MAJOR THERMAL ELECTRIC STATIONS IN THE USSR

Table F-8

MAXIMUM POWER STATION SIZES
AND STEAM PARAMETERS IN THE USSR

Station Sizes and Steam Parameters	Condensing Turbines (GRES) 1950	1970	1975	Electric Power and Heat Turbines (TETS) 1950	1970	1975
Max. station capacity (MW)	510	2,440	3,000	150	600	1,000
Max. turbogenerator size (MW)	100	800	1,200	25	100	250
Max. boiler capacity (metric tons/hr.)	230	1,250	3,600	230	480	950
Initial steam parameters at turbine inlet						
Pressure, Kg/cm^2	90	240	240	90	130	240
Temperature, ^{o}C	500	565	565	500	565	565
Second reheat, ^{o}C	-	565	565	-	-	565

(240 Kg/cm^2) at 1,049°F (565°C). Although research is being done on the use of higher pressures, the Soviet planners have decided to keep the maximum inlet steam temperature at 1,049°F. Economics and lack of high quality austenitic steel prevented them from going to higher temperatures. In the United States, one plant has been operating in the supercritical region with a pressure of 5,000 psi and 1,200°F. This, however, is not the norm in the United States either, and most operations are limited to 5,000 psig and 1,100°F on economic grounds.

A number of plants (GRES) are being constructed, at present, with individual turbine capacities of 800 MW, and at least one is

Table F-9

BREAKDOWN OF INSTALLED STEAM TURBINE, THERMAL STATION CAPACITY IN THE USSR BY TURBOGENERATOR SIZES (1,000 MW)

Capacity	Condensing Turbines			Heat and Power Turbines		
	1965	1970	1975	1965	1970	1975
Turbogenerator size (MW)						
800	-	0.8	3.2	-	-	-
500	-	0.5	1.5	-	-	--
300	3.6	20.7	37.2	-	-	-
250	-	-	-	-	-	1.5
200	9.6	16.6	22.6	-	-	-
170	-	-	-	-	-	0.17
160	8.96	12.32	13.44	-	-	-
150	0.6	0.6	0.6	-	-	-
135	-	-	-	-	-	0.405
100	8.4	9.5	11	1.3	5.1	11.7
< 100	17	15.05	10	31.4	41.9	51.225
Total	48.16	76.07	99.54	32.7	47	65
Inlet steam pressure (Kg/cm^2)						
300	-	0.1	0.1	-	-	-
240	3.6	22	41.9	-	-	1.5
200	0.05	0.05	0.05	-	-	-
170	0.6	0.6	0.6	-	-	-
130	18.56	29	36.32	9.7	18.2	30.9
60-120	-	-	-	2.7	2.7	2.7
90	16.95	17.35	17.37	7.3	12.55	15.3
35 and less	8.4	6.97	3.2	13	13.55	14.6
Total	48.16	76.07	99.54	32.7	47	65
Type of steam draw-off						
Steam for water heating				9	15.4	25.6
Direct steam and water heating				13.6	19.9	25.4
Direct steam				10.1	11.7	14
Total				32.7	47	65

Source: Energetika SSSR v 1971-1975 Godakh, Pub. "Energia," Moscow 1970, pp. 108-110.

reported to be of 1,200 MW size. The largest share of new installations will have 300 MW units installed. There should be 55 turbines of this capacity installed between 1970 and 1975, for a total of 124. The second largest share of installed capacity will have 200 MW turbines, with a total of 30 turbines to be installed in the same period for a total number in 1975 of 113. Only three new turbines of 800 MW capacity are scheduled for installation in the 1971-1975 plan period.

Construction is in progress on new stations such as the one in Uzbek SSR, Central Asia, near the town of Bekabada. The installed capacity of this station is scheduled to reach the projected design capacity of 4,400 kW by 1980. It is to consist of four turbines of 300 MW and four of 800 MW capacity each. The first 300 MW block was put into operation in late 1972 and is being fueled by natural gas.[5,6]

Some of the smaller condensing type turbine installations are being shifted to operate as heat and power turbines in order to meet the planned expansion of supplies of hot water for centralized public space heating. By increasing the production of heat in electric stations, the Soviet planners hope to reduce the overall fuel consumption for space heating by the less economic district boilers.

2. Economic Considerations for Installation of Heat and Power Turbines

In their overall search for the most economic utilization of fuels, the Soviet planners have arrived at certain economic criteria for installation of heat and power stations.

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[5] Ekonomicheskaya gazeta (Economic Newspaper), No. 13 (March 1973) and No. 28 (July 1973).

[6] "Elektrifikatsia SSSR," in Energia, P. P. Neporozhnego, ed., p. 239 (Moscow, 1970).

They have concluded that the overall savings in fuel corresponding to combined heat and power production is justified only in instances where amortized costs of these more expensive installations and the regional price of fuel are such that it becomes uneconomic to install separate boilers for heat production. Installation of high capacity heat and power turbines such as T-250-240 (250 MW, supercritical steam) is reserved for cities with populations over 1 million located in regions of high fuel costs (fuel costs over 12 rubles/metric ton coal equivalent).* This restriction limits introduction of these large turbines to the European part of the USSR. They are presently being installed at Moscow and Kiev. Installation of heat and power turbines of the 250 MW capacity in thermal power stations at Leningrad, Kharkov, and Minsk are scheduled for the period 1976-1980.

Heat and power turbines of the 100 MW capacity (T-100-300) are installed throughout the USSR in cities with populations of 250,000 to 1 million, with the exception of cities in southern regions where the winter heating season is relatively short.

There are no current plans to raise the power levels of the heat and power turbines any higher, except for development of 170 MW turbines, which will be introduced in areas with high consumption potential but with low fuel costs.

3. Fuel Consumption in Soviet Thermal Plants

Electric power generation is the biggest single fuel consuming industry in the USSR. The projected growth in electric power generation is going to increase its share of fuel consumption even further. Whereas in 1960 it accounted for about 30 percent of all fuel

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* One metric ton coal equivalent = 27.78 million Btu.

consumed in the country, by 1975 this share will climb to 37 percent. With this fact in view, it becomes important to look at the efficiency of fuel utilization in Soviet thermal stations.

It is easy to see, by examining the historical trends in heat rates in Soviet power stations (Table F-10), that the growth in installed capacity has been paralleled by dramatically decreasing heat rates. Without higher capacity/higher efficiency units, the supply of fuel to electric stations would have become critical. Further expansion of generating capacity will have to call for further reductions in fuel consumption.

The average heat rates for all thermal plants in the USSR lagged rather significantly behind those of the United States in the early sixties, but have since become similar. It appears, too, that the program of rapid introduction of new supercritical units and phasing out of obsolete plants in the USSR will further improve the net heat rates. The plans call for the heat rate to drop to 9,444 Btu/kWh by 1976 in all public thermal stations, which should lower the overall heat rate to a figure somewhat lower than that in the United States.

Another dramatic change that was partly responsible for the lowering in specific fuel consumption in electric stations was the change in structure of fuels used in thermal stations over the last 15 years. Fuel use and regional utilization of fuels by type are given in Tables F-11 and F-12, respectively. Two features are of note. The first is the change to oil and natural gas, which accounted for almost 49 percent of total fuel used in 1970, and the second is the still significant use of peat and shale in certain regions of the USSR. The use of peat, shale, and low grade coal is justified on economic grounds in certain regions that lack gas and oil resources.

Table F-10

NET HEAT RATES FOR POWER GENERATION IN THE USSR

Year	% of All Thermal Power Generated by Public Thermal Stations*	Net Heat Rates for Public Thermal Stations Btu/kWh†	Net Heat Rates for All Thermal Stations Btu/kWh‡	Net Heat Rates for All U.S. Thermal Stations Btu/kWh§
1955	70.1	14,528		11,699
1960	72.7	13,000	14,157	10,701
1961	71.8	12,750		10,552
1962	72.4	12,444		10,497
1963	76.5	12,167		10,438
1964	83.6	11,889		10,407
1965	85.4	11,528	12,096	10,384
1966	86.5	11,250		10,399
1967	88.1	10,944		10,396
1968	88.8	10,694		10,371
1969	89.7	10,472		10,457
1970	90.5	10,194	10,459	10,508
1971	91.2	9,972		10,536
1975 Plan		9,444**		

* United Nations Electric Energy Statistics for Europe, various annuals; also UN Series J publications, 1960-1970, pp. 293, 344.

† Narodnoie Khoziaistvo (National Economy), Statistical Annuals of the Central Statistical Bureau of the USSR.

‡ SRI estimate; calculated by dividing total reported fuel consumption (from Energetika SSSR v 1971-1975 Godakh, Pub. "Energia," Moscow 1972, p. 170) by net power generation (after subtracting fuel used for heat generation).

§ Federal Power Commission Report FDC, Hydroelectric Power Evaluation, 1968, p. 35; SRI calculations.

** Energetika SSSR v 1971-1975 Godakh, Pub. "Energia," Moscow 1972, p. 97.

Table F-11

FUEL USE IN ELECTRIC POWER STATIONS IN THE USSR BY TYPE
(Percent)

	1960	1965	1970	1975
Gas	12.3%	25.6%	26 %	26.8%
Liquid fuel	7.5	12.8	22.5	25.1
Coal	70.9	54.6	46.1	42.6
Peat	7	4.5	3.1	3.5
Oil shale	1	1.5	1.7	1.6
Others	1.3	1	0.6	0.4
Total	100	100	100	100

Source: Energetika SSSR v 1971-1975 Godakh, Pub. "Energia," Moscow 1972, pp. 171-173.

Most of the coal supplied to the thermal stations in the European part of the USSR in 1965 came from the Donets basin. However, with large new demands on coking coal for the production of iron, Donets coal is being replaced by the coal from the Kuznetz basin as well as other fuels. Because of substantial pollution caused in burning this coal, a change to other fuels is being considered for the stations that are located near large cities such as Moscow and Ryazan and that are supplied with coal from the sub-Moscow basin. To further reduce consumption of the Donets coal, a number of large stations planned for the western part of the USSR, such as at Pskov, Smolensk, and Cherepovets,

Table F-12

REGIONAL FUEL USE BY TYPE
(Percent)

Regions of USSR	Total 1965	Total 1969	Gas 1965	Gas 1969	Liquid Fuel 1965	Liquid Fuel 1969	Coal 1965	Coal 1969	Peat 1965	Peat 1969	Oil Shale 1965	Oil Shale 1969	Other Fuels 1965	Other Fuels 1969
RSFSR; Total	100	100	22.6	22.8	12.5	21.5	57.8	50.4	5.2	4.1	0.4	0.3	1.5	0.9
European Part	100	100	31.3	25.1	16.7	32	41.0	35.1	8.65	6.3	0.75	0.5	1.6	1
Urals	100	100	22.7	37.4	6.8	6.3	66.5	53.7	2.3	2.1	-	-	1.7	0.5
East	100	100	2	2.3	8.2	8.2	89	88.2	-	-	-	-	0.8	1.3
Ukraine and Moldovian SSR	100	100	35.7	34.7	7.3	7.9	56.6	57.3	0.3	0.1	-	-	0.1	-
Belorussia	100	100	23.1	16	10.9	20.5	28.3	39.1	37.6	24	-	-	0.1	0.4
Baltic Republics	100	100	19.4	14.5	11.6	28.5	5.7	3.4	11.2	7.7	51.6	45.4	0.5	0.4
Caucasus	100	100	32.3	19	58.5	76.8	9.2	4.2	-	-	-	-	-	-
Kazakh SSR	100	100	7.7	11.5	11.6	12.1	80.7	76.4	-	-	-	-	-	-
Central Asia	100	100	44	61.8	18	16	38	22.2	-	-	-	-	-	-
USSR; Total	100	100	25.6	25.3	12.8	20.2	54.6	48.9	4.5	3.4	1.5	1.55	1	0.65

Source: Energetika SSSR v 1971-1975 Godakh, Pub. "Energia," Moscow 1972, pp. 171-173.

are intended to burn peat. However, the major part of new fuel demands is to be supplied by gas and fuel oil for the European part of the USSR.

The situation in the Urals is somewhat different. There the future plans call for utilization of the Ekibastuz coal in large quantities. Already in 1965 almost 73 percent of total production of this coal was delivered to this region. Further development of strip mining in this basin makes this coal, according to Soviet planners, competitive with natural gas. Natural gas is abundantly available in this region because of a network of gas pipelines running through the region. It is expected that Ekibastuz coal will account for 25 percent of all fuel consumed in the Urals by 1975.

Thermal stations in the eastern regions burn primarily local coals and are likely to stay on these fuels for the near future. In particular, the strip-mined coals of the Kuznetsk and the Kansko-Achinsk basins are going to be the main suppliers of coals to those stations. However, some boilers, working to cover peak demands, will be fueled by fuel oil. This is being justified on the basis of lower capital costs than for boilers working on coal.

Seasonal variations in heat and power demands cause relative perturbations in supplies of different fuels. Because of high demands placed during the winter months by households and direct industrial users, natural gas supplies to electric stations are drastically curtailed, thus requiring stations to shift some, and sometimes all, of their load to coal or fuel oil. Hence, during the winter months, thermal stations use more coal and fuel oil relative to natural gas than they do in the summer months. This method of operation in turn requires installation of facilities at these stations so that they will be able to shift from one fuel to the other. Usually the boilers are manufactured to work either on coal and gas or on fuel oil and gas. The wide

variations in coal quality require construction of special boilers for a particular station, and the shift in coal type then requires reconstruction of existing facilities.

D. Nuclear Power

The first successful test of an atomic reactor in the USSR occurred on Christmas Day 1945 about three years after an American reactor achieved criticality. A Soviet test fission weapon was set off on August 29, 1949. Five years later, in June 1954, the USSR's first atomic power station began producing electricity at Obninsk outside Moscow. The rated electrical power was 5 MW. Since 1954, the total installed nuclear capacity in the USSR has increased to about 500 times that figure (at seven locations). In another decade, the USSR's installed nuclear capacity will be 20 times the present amount.

This rapid rate of growth indicates the importance of the nuclear reactor to the USSR national plans for resource development and the generation of electricity. In addition to their efforts to use uranium-235 fission, a considerable research program is devoted to the magnetic containment of high temperature plasmas to study the possibilities of deriving energy from controlled thermonuclear fusion of deuterium and tritium. In this area the USSR leads the rest of the world with the design of its toroidal shaped "tokomak" at Khurchatov Institute. However, even with this recent impressive success, it is not anticipated that a successful fusion reactor will become reality before the end of the present study period (1990). Beyond that are the formidable engineering problems of withdrawing energy and generating electricity from this process--

problems that may not be solved in this century. Consequently, we shall not discuss the fusion research program in any detail.*

The Soviet program for generating electric power from nuclear fission is characterized by these main features:

- Historical reliance on the Light Water Reactor (LWR) for power generation from conversion reactors.
- National commitment to development of the oxide-fueled liquid metal fast breeder reactor (LMFBR).
- Early construction of LMFBR demonstration power plants instead of reactor test facilities.
- Low reserves and capacity for plutonium production and little experience with plutonium or mixed oxide fuels.
- Recent reemphasis on newly designed graphite-moderated thermal converter reactors for power and plutonium production until widespread use of the LMFBR is ready (probably beyond 1985).
- Dependence upon development of nuclear power with highly flexible plant load factors.
- Specialized uses of nuclear plants for space heating and desalination of water in addition to production of electricity.
- Less concern for including safety features to cover small probability (or "incredible") failures.

These features have important implications for the rate of development of the Soviet power reactor program and for estimates of future electrical capacity.

1. Status of Nuclear Power Industry in the USSR

The installed capacity of nuclear power plants in the USSR at present (2,320 MW) is considerably smaller than that of the comparable

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* An excellent summary of the Soviet fusion research program appears in American Scientist, Volume 59, p. 463.

U.S. industry (20,000 MW). However, it is estimated that Soviet installed nuclear capacity will reach 7,120 MW by 1975 and 21,000 MW by 1980.

A summary of known power reactors either in operation or being constructed in the USSR is given in Table F-13 by year of completion, location, type, and size. From this table it is obvious that in the past the Soviets have emphasized variations of the Light Water Reactor (LWR) in their construction program. This emphasis and the principal design features of the LWR power plants have been substantially similar to the program in the United States and Europe.

The locations of the installations listed in Table F-13 are illustrated in Figure F-6. Because the supply of nuclear fuel is not a substantial cost (one trainload shipment a year is adequate to supply even the largest installation), it is anticipated that nuclear plants will be located close to the major demand markets, except for auxiliary uses such as desalination of water (Shevchenko) or space heating (North-East). Furthermore, a 1971 Russian study indicated that only in the principal regions of Siberia is nuclear power uneconomical in comparison with electrical plants burning local coal or possessing large hydroelectric power stations. Therefore, it should be expected that future locations of reactors will be widespread throughout the European USSR, perhaps 20 to 30 kilometers outside major cities.

2. Plans for Reactor Development and Construction Costs

The Soviet plan appears now to be based on simultaneous development of the oxide-fueled Liquid Metal Fast Breeder Reactor (LMFBR) and a light water-cooled, graphite moderated nonbreeder (LWGR) with modified design features.

Table F-13

USSR POWER REACTORS IN OPERATION OR UNDER CONSTRUCTION

Year	Location	Type	Power (1,000 MWe)	Cumulative (1,000 MWe)	Construction Cost (rubles/kWe)
1954	Obninsk	TEST	0.005		
1964	Troitsk	LWGR	0.60		
	Novo-Voronezh - No. 1	PWR	0.21		
	Beloyarsk - No. 1	LWGR	0.09		704
1966	Melekess	BWR	0.05	0.95	
1967	Beloyarsk - No. 2	LWGR	0.20		224
1969	Novo-Voronezh - No. 2	PWR	0.37		
1970	Melekess	FBR	0.01	1.53	
1971	Novo-Voronezh - No. 3	PWR	0.44		210
1973	Shevchenko	FBR	0.35		
	Novo-Voronezh - No. 4	PWR	0.44	2.76	
1975	Oktomberyan - No. 1,2	PWR	0.88		
	Murmansk - No. 1	PWR	0.88		
	Novo-Vorenezh - No. 5	PWR	1.00		
	Beloyarsk - No. 3	FBR	0.60		225
	Leningrad	LWGR	1.00	7.12	120
1980	Leningrad	LWGR	1.00		
	Smolensk - No. 1,2	LWGR	2.00		
	Kiev - No. 1,2	LWGR	2.00		
	Kursk - No. 1,2	LWGR	2.00		
		PWRs (est.)	6.0		
		FBRs (est.)	1.0	21	

BWR - Boiling Water Reactor.
PWR - Pressurized Water Reactor.
LWGR - Light Water Cooled, Graphite Moderated Reactor.
FBR - Fast Breeder Reactor.

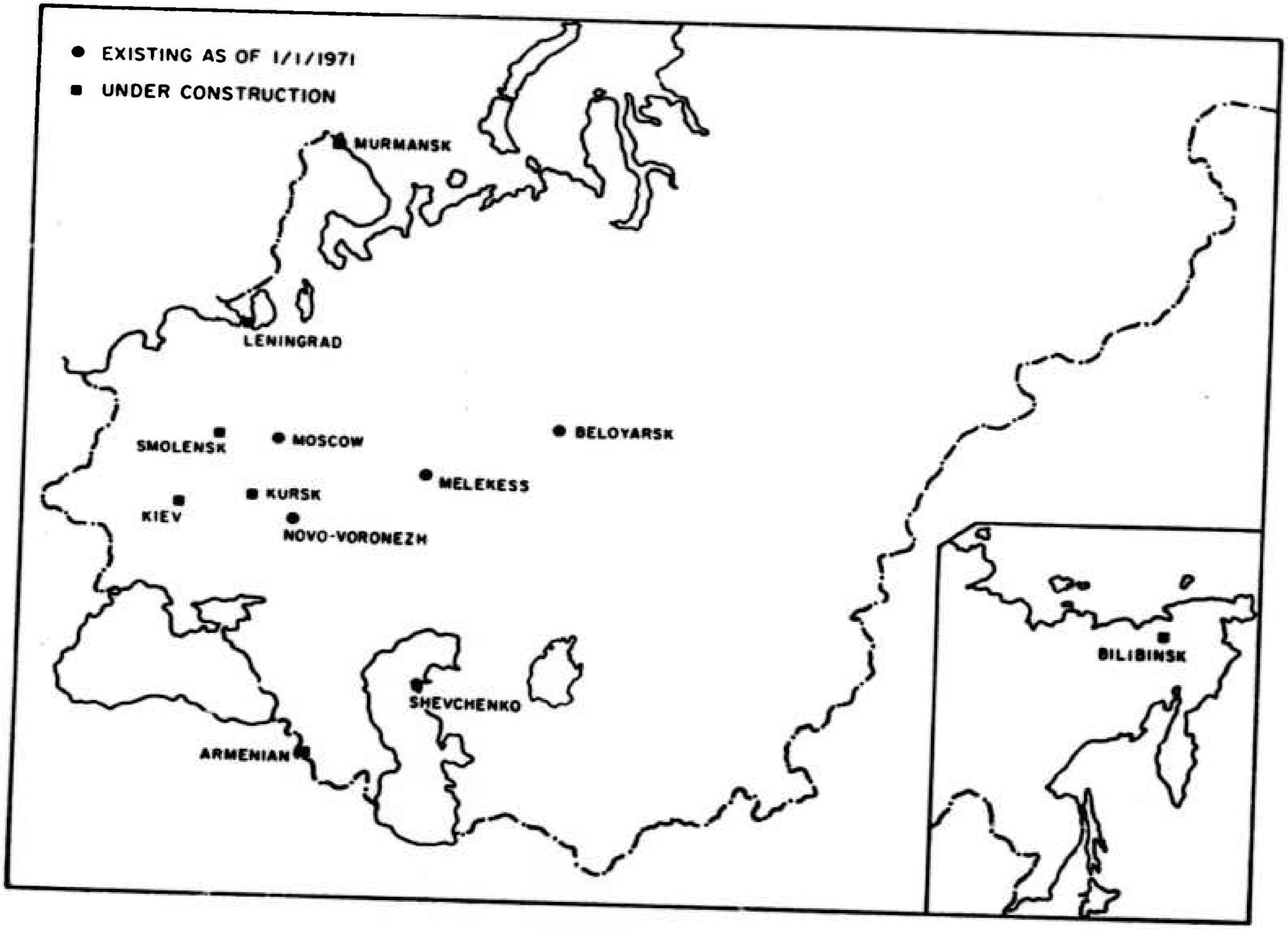

Figure F-6

LOCATIONS OF NUCLEAR POWER PLANTS IN THE USSR

The two largest LMFBR demonstration plants in the world are both being constructed in the USSR; one of these is close to completion, several years ahead of the schedule for an American breeder of comparable size. This lead is primarily a result of a Soviet decision for the early construction of demonstration power plants instead of reactor test facilities as is planned in the United States. By sacrificing an early demonstration of power generation from breeder reactors, the U.S. approach allows much greater flexibility in making design modifications during the development of the high performance systems required to satisfy power industry needs. The Soviet program seems to be based on the conviction that the problems of developing high performance breeder systems can best be worked out with experience gained from demonstration power plants.

One possible restriction on early wide-scale adoption of the LMFBR by the Soviets is the comparatively limited supply and rate of production of plutonium in the USSR.

Plutonium is used as the principal fuel for the initial charge in the U.S. design of the fast breeder where about 4,000 kilograms of fissile material is required in the fuel cycle for each 2,000 MWe generated. After the initial loading, however, the breeder produces more plutonium than it consumes, converting the abundant, non-fissioning uranium isotope (U-238) into plutonium. Estimates of the USSR supply of plutonium from reprocessing the fuel elements of converter reactors do not exceed about 10,000 kilograms (10 tons) by 1980.* To overcome this problem of plutonium shortage, the Soviets have designed their breeder to be compatible with the initial use of uranium oxide fuel elements and subsequent conversion to plutonium or mixed oxide fuels as they become available.

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* As compared with about 100,000 kilograms of plutonium from convertor reactors in the United States.

The limited USSR supply of plutonium can be traced to the smaller number and size of their conventional reactors both operating and under construction. It is not known to what extent plutonium can be produced and diverted from the weapons program for use in the power reactors, but the Soviet plan to sacrifice some performance in these reactors by designing them for compatible use with uranium oxide fuel elements probably indicates that very little, if any, plutonium can be expected from that source.

As indicated previously, the conventional reactor program in the USSR has emphasized the construction of Pressurized Water Reactors. There is now evidence that considerable effort is being devoted to a modernized version of the old graphite moderated reactor. The Soviets indicate that some design changes in the original concept of this reactor will enable them to make significant reductions in construction costs. The quoted figures for construction costs are given in Table F-13 for several reactors of different design, including the first of two 1,000 MWe graphite reactors presently under construction in Leningrad. There is some question about whether all capitalization costs have been included in these figures, but assuming that the method of calculation is self-consistent, it is clear that the construction costs for the new graphite reactors are lower than for PWRs. In addition, the conversion ratio for production of much needed plutonium from fertile U-238 is higher for graphite reactors (0.7) than for PWRs (0.6).

There has been no indication of any USSR plans to pursue development of the High Temperature Gas Reactor (HTGR) which is receiving much attention in the United States and the United Kingdom. The HTGR, a thermal converter based on the thorium cycle, will probably dominate the Western reactor market during the 1980s (before large-scale introduction of commercial breeder reactors) because of its high thermodynamic efficiency (up to 43%) and lower costs. The HTGR uses a

uranium-thorium fuel mixture and converts thorium-232 into fissile uranium-233. The U-233 can be recovered for use as a fuel in certain thermal breeder reactors, e.g., the Molten Salt Breeder Reactor (MSBR), but it is not very useful in fast breeders. The HTGR may not be attractive to the Soviets because of their substantially different nuclear fuel supply picture and their commitment to ultimate emphasis of the LMFBR.

Despite the considerable effort being devoted to improvement of the fast breeder and the early construction of large demonstration power plants at Shevchenko and Beloyarsk, it is not expected that any significant production of electricity on a national scale will come from this source much before 1990. However, until such time as the breeder is producing at least as much fissile material as is being consumed in reactors throughout the USSR, uranium ore will be adequate to supply all Soviet reactors with fuel at about the same cost as 1973 supplies.

3. Growth Projections and Comparative Power Costs

Projecting the growth of Soviet nuclear power generation by comparison of costs with fossil fuel power has always been restricted by the lack of actual performance and cost data for existing reactor types. U.S. scientific delegations visiting Soviet reactor sites have had little success in determining the basis for the Soviet cost figures that were provided. Furthermore, the technology of only a few reactor designs has matured to the point where one can estimate with confidence the costs of a full-scale plant of a size likely to be competitive with fossil fueled plants. Fuel cycle costs are changing rapidly as a result of innovations in the design and manufacture of fuel elements. Recent changes in Soviet policy on reactor safety requirements may also substantially affect costs. Finally, any large-scale introduction of

nuclear energy will undoubtedly affect the economic picture for traditional energy resources, displacing the more expensive fuels from use in electric power generation and thereby altering its own economic environment--i.e., important "feedback" mechanisms begin to operate.

In recognizing that inter-fuel competition will make isolated economic comparisons obsolete, Soviet economists themselves have adopted a new approach to forecasting the growth of nuclear power. They are using a mathematical model that simulates the power economy of the USSR and makes forecasting predictions based upon many different combinations of economic variables. Some of these variables are: total electric power consumption, potential volume of coal and petroleum production, total capacity of nuclear electric plants, operating characteristics of the plants (thermodynamic efficiencies, conversion ratios, etc.), territorial distributions of different types of plants, and costs in each category of production and in each end-market sector.

A summary of the historical and projected nuclear capacity has been given in Figure F-1 and Table F-3. Starting from less than 1 percent of the total in 1970, it is anticipated that nuclear capacity will rise rapidly and overtake hydroelectric capacity by 1990, when each will be over 100,000 MW. Furthermore, because much of the hydroelectric power is reserved for peak load demands whereas nuclear installations are primarily for base load, the total electrical energy generated by reactor installations (in kilowatt hours) will substantially exceed hydroelectric energy, as can be seen from the projected figures in Table F-4.

By 1990 we expect the following:

- Nuclear plants with load factors flexible enough that they can be used for either base or some peak load operations.

- Total nuclear energy will be 7-8 percent of total energy consumption (oil, gas, coal, hydro, nuclear).
- The proportion of installed nuclear capacity to total capacity will be 20-23 percent (including 32-36 percent in the European USSR).
- The growth rate of nuclear power will not be very sensitive to the price of other energy resources as long as the relative capital investment in nuclear plants does not exceed the capital investment in fossil fuel plants by more than 50 percent.
- Nuclear plants will be used to provide for the growth of base load and some fluctuating electric load in the North-West, Center, Ukraine, and Caucasus. No special effort will be made to extend nuclear use either to other regions (Siberia) or to still more fluctuating portions of the load curve.
- Most nuclear power will be generated about equally from Pressurized Water Reactors and Graphite Moderated Reactors with LMFBRs just beginning to emerge from the testing stage to full-scale production and use as indicated in Table F-14.

Table F-14

FORECAST USSR INSTALLED CAPACITY BY REACTOR TYPE
(1,000 MWe)

	1975	1980	1985	1990
PWR	4.2	10	23	50
LWGR	1.9	9	23	53
LMFBR	1.0	1	3	6
Others	-	1	4	9
Total	7.1	21	53	118

Finally, it should be mentioned that the Soviets are using nuclear energy for specialized purposes, such as desalination of sea water and power generation combined with space heating in remote regions where the growth of mining activity has been restricted by limited fuel supplies and severe climatic conditions. In many ways, nuclear energy is an excellent solution to these problems.

At the town of Schevchenko on the Caspian Sea, the BN-350 experimental LMFBR produces almost 20 million gallons per day of desalinated water for 60,000 people. The water is used for direct consumption, industry, and agriculture. Although the expense is rather high (over $2.00 per thousand gallons) it is the only plentiful supply of fresh water in this desert region where rich reserves of manganese and phosphorites provide the incentive for industrialization.

In extremely remote arctic areas of the Asian North where supply lines from developed districts often extend several thousand miles, the problems of maintaining a reliable fuel supply has hampered industrial development. Considerable deposits of copper, nickel, tin, gold, and diamonds have been discovered but are not exploited because of fuel transportation costs which are often more than five times the costs for economically developed regions. Small nuclear plants generating less than 50 MW electrical power and providing turbine exhaust steam for local space heating may be a key to Soviet **development** of these resources.

E. Electric Transmission System in the USSR

In order to centralize power production and use the savings inherent in large power producing complexes, a large transmission grid had to be built rapidly in the USSR in order to embrace the vast territories of the country.

The rapid growth in transmission facilities that took place in the last ten or so years can be observed in the statistics for total length of transmission lines of various voltages (Table F-15).

Table F-15

LENGTH OF TRANSMISSION LINES IN THE USSR

Transmission Voltage (kV)	Length of Transmission Lines with Voltages Greater Than 35 kV (thousand km)			
	1960	1965	1970	1975 Plan
750-800	-	0.4*	0.56	2.15
500	2.4	8.17	13.14	21.0
400	2.1†	0.11	0.55	0.55
330	1.0	7.0	13.4	21.4
220	15.4	35.1	50.8	70.0
154	2.0	5.1	5.5	5.5
160	81.2	134.9	185.0	240.00
35	63.1	121.1	175.3	245.0
35-800	167.2	312.05	444.25	605.6

* DC line.

† Of the 2.1 thousand km, 2.0 thousand was upgraded to 500 kV by 1965.

The high voltage lines of 750 kV will be used for transmission of power from the largest stations as well as interconnections between the various electric regional grids, both in the European and the Siberian parts of the country. The 400 kV lines are used exclusively for tying in the COMECON systems with the unified system of southern European Russia. 750 kV lines are being used in tying in the grids of the Caucasus, the South, the Volga, the Urals, the Center, and the Northwest into one unified system in the European part of the USSR. Other lines of 500 kV will tie in the Siberian grids with those of the European part of the country. The electric transmission system of 330-750 kV lines of the USSR is shown in Figure F-7.

Present plans call for the building of large thermal stations burning coals of the Kansk-Achinsk basin in Siberia, and for the transmission of power thus generated to the Urals by means of the proposed tie-ins between the Siberian and the European systems.

The chronic shortage of peak power capacity in the Soviet electric systems has been somewhat alleviated with the integration of the transmission systems into one unified grid in the European part of the USSR. The total load over time has been somewhat leveled off because of the time difference in the various areas constituting this system. However, at the same time, the introduction of larger base-load thermal plants and the leveling off of the hydrostation construction have not allowed the Soviets to build adequate reserve capacity for peaking loads. This situation has been further complicated by the introduction of the five-day work week in 1966 and 1967.

The Soviets have had an experimental 800 kV DC line 475 km long and a 750 kV AC line 100 km long operating since about 1965.

The present plans call for wide introduction of 750 kV AC lines in the 1971-1975 period and the development of even higher voltage lines of 1,500 kV DC and 1,150 kV AC after that.

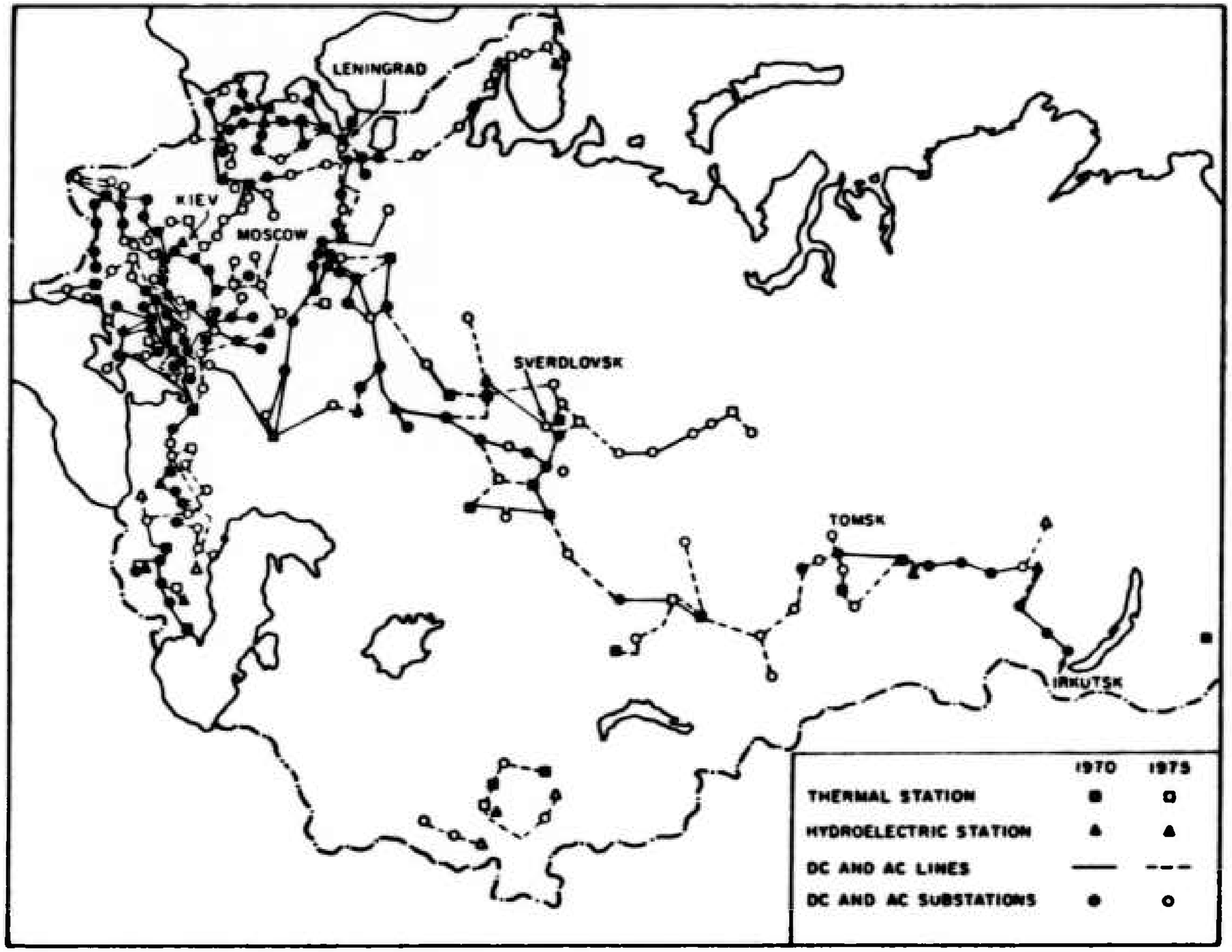
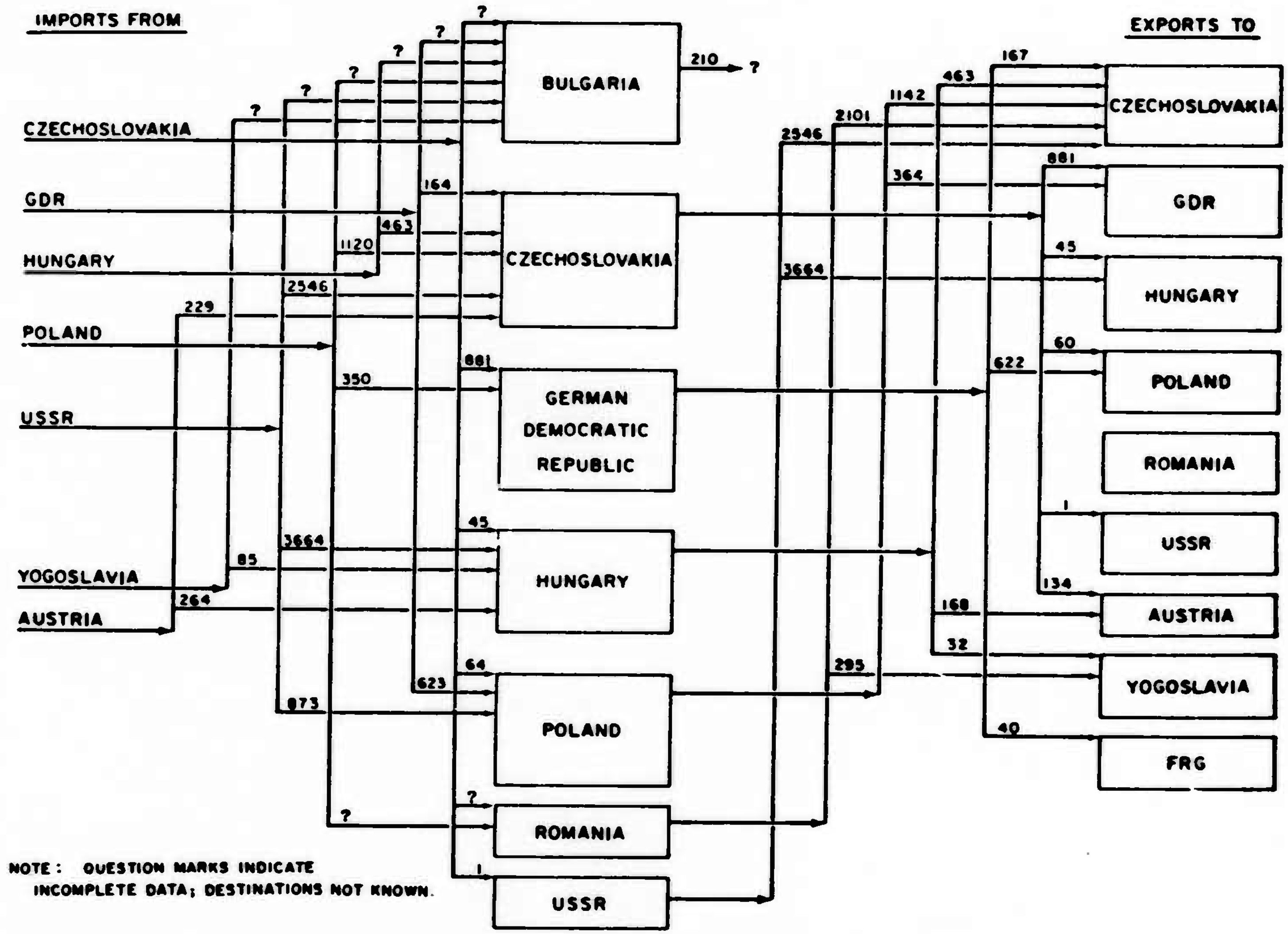


Figure F-7

ELECTRIC POWER TRANSMISSION GRID OF THE USSR
(330 to 750 KV)

Patterns of movement of electric energy among countries in Eastern Europe are shown as of 1970 in Figure F-8. This figure shows that the USSR is the largest single exporter of electric energy, with Romania being the next largest exporter, and Czechoslovakia third. Czechoslovakia is the largest importer of electric energy, Hungary is next, and Poland is third. The following countries are net importers of electric energy: Czechoslovakia, Hungary, German Democratic Republic, Poland, and Bulgaria. Romania and the USSR are net exporters of electric energy.



NOTE: QUESTION MARKS INDICATE INCOMPLETE DATA; DESTINATIONS NOT KNOWN.

Figure F-8
PATTERNS OF ELECTRIC ENERGY MOVEMENT IN EASTERN EUROPE - 1970
(Gigawatt Hours)

III ELECTRIC POWER STATIONS IN EASTERN EUROPE

A. Present and Future States of Nuclear Power

1. East European Bloc

The East European countries have a considerable stake in the development of nuclear electrification programs. An enormous investment of human and economic resources will be necessary to assure an adequate supply of power to meet their own projected demands for industrial development. For many of these nations, short in domestic supplies of fossil fuels and undeveloped hydroelectric possibilities, nuclear energy represents their only alternative to massive import of fuel from uncertain supply channels.

Although ambitious plans have been announced in many of these countries (Bulgaria still anticipates reaching 11,300 million kilowatt hours from nuclear plants by 1978), actual development has been considerably slower in most. Only the German Democratic Republic, Czechoslovakia, and Bulgaria have a substantial nuclear electrification program at present, although Hungary, Poland, and Romania have laid much of the ground work for future development. Table F-16 gives a summary of the projected growth of nuclear installed capacities and production of electricity for each of these countries to 1990.

2. Czechoslovakia

The Czechoslovak experience is a good example of what can usually be expected in the development of sophisticated technology in nations lacking prior experience in the field. From their own reports:

Table F-16

NUCLEAR INSTALLED CAPACITIES AND PRODUCTION
(Capacity - MWe; Production - MkWh)

	1970	1975	1980	1985	1990
USSR					
Installed capacity	1,400	7,100	21,000	53,000	118,000
Production	3,600	25,000	95,000	255,000	670,000
Bulgaria					
Installed capacity	-	440	880	1,760	3,500
Production	-	385	2,500	5,500	12,000
Czechoslovakia					
Installed capacity	-	600	1,800	3,600	6,000
Production	-	1,035	3,000	6,000	15,000
German Democratic Republic					
Installed capacity	-	1,000*	2,000	4,000	7,000
Production	464	2,300	6,000	10,000	20,000
Hungary					
Installed capacity	-	-	440	880	1,760
Production	-	-	480	2,000	5,000
Poland					
Installed capacity	-	-	-	440	880
Production	-	-	-	1,000	3,000
Romania					
Installed capacity	-	-	-	440	880
Production	-	-	-	1,000	3,000

* Voprosy ekonomiki, No. 2, 1973, p. 79.

"The country's initial plans were very far-reaching. Nuclear power generation was to be developed rapidly on the basis of gas-cooled, heavy-water reactors burning natural metallic uranium. The construction of a prototype gradually gave rise to technological problems which could be overcome only by creating an appropriate scientific and manufacturing base. Through concentration of the efforts of the country's main engineering enterprises, the first Czechoslovakian nuclear power station is now ready for operation...the delay in completing the construction of the prototype station and the experience gained during construction have made it clear that a prerequisite for the rapid growth of nuclear power... is wider international co-operation in the manufacture of equipment for nuclear power stations."

The present Czechoslovak program of nuclear electric power development entails the construction of two stations of the Voronezh type, with a total capacity of 1,700 MWe. One of these will be built in Slovakia, the other in Southern Moravia along with the hydroelectric power station "Dalishitse" on the Yiglave River. By 1980 both of these nuclear power plants, to be built with the technical assistance of the USSR, should be producing about 4 Billion kWh of electricity and probably three times that amount by 1985. Along with the construction of reactors of the Voronezh type, the Czechs plan to shift to larger, thousand-megawatt reactors as the demand arises.

3. German Democratic Republic

The German Democratic Republic has had considerably more success in its nuclear electrification program. This success can be attributed, at least partially, to a more industrialized, technological economy and population than exists in the other satellite nations. As

a result, the Germans have been able to complete construction and obtain power from Pressurized Water Reactor plants within two years of the time when prototype plants were first completed in the USSR. The construction techniques and standardization accomplished in assembly of these installations may prove very significant for future development of atomic power within the GDR and all of Eastern Europe. The GDR plans to install several of these standardized 880 megawatt PWRs in the next few years. If they continue to have the same success, it is likely that Bulgaria and Czechoslovakia will adopt the same prefabrication techniques to accelerate their own construction programs.

B. Production of Electricity

1. Electric Power Generation in Bulgaria

Bulgaria occupies fourth place in the per capita production and consumption of electric energy in Eastern Europe. The total electric power generation in Bulgaria amounted to 19,513 million kWh in 1970, with hydroelectric power generation accounting for 11 percent of this total. There is at present no production of electric power by nuclear plants; however, they are planned to have a very significant role in the future, and one is being constructed during this five-year plan period.

The share of hydroelectric power generation in total electric power production is declining and has dropped to the present level of about 10 percent (in 1971) from about 40 percent in 1960. It will probably decline still further, in view of ambitious schemes for construction of thermal and nuclear plants. At present, approximately 20 percent of economically developable hydroelectric potential of the country

is being utilized, and it is unlikely that any significant hydroelectric projects are being planned for the near future.*

As in other Eastern European countries, a significant portion of the thermal stations is devoted to production of heat in the form of hot water and steam for industry and residential space heating. In 1960 about 34 percent of all electricity generated was represented by this type of station. It is also expected that these heat and power stations will represent 23 to 25 percent of all electricity generated by 1980. Table F-17 shows the generation of electric power in Bulgaria by types of stations, with Bulgarian projections for the future.†

Fuel type usage in thermal power stations and fuel consumption in public thermal stations are shown in Tables F-18 and F-19, respectively. As can be seen in Table F-18, the main fuel used in Bulgarian power stations is lignite, which accounted for almost 72 percent in 1967. In view of a limited, economically developable fuel resource base, the Bulgarian prognosticators envisage the peaking of production of their low grades of coals and lignite around 1980, and all future growth in thermal station fuel usage will be with oil and natural gas. These, of course, would have to be imported from either the USSR or the Middle East.

To cover the deficit of electric power, the Bulgarians expect to develop almost all of their hydroelectric capacity by the year 2000. This solution, as the Bulgarians themselves admit, is extremely costly and is unlikely to happen. Realistically, perhaps no more than 6,000

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* The Bulgarian projections for hydroelectric power development in the future are unrealistic, as they themselves admit. (See Table F-17.)

† Most Soviet satellite information on electric energy was compiled from USSR sources; references are given at the end of this appendix. Projections are from these same sources, and were reported by the Soviets from estimates made by the country of origin.

Table F-17

GENERATION OF ELECTRIC POWER IN BULGARIA BY TYPES OF POWER STATIONS*
(Million kWh)

Year	Thermal Plants: Steam: Heat/Power	Thermal Plants: Steam: Condensing	Thermal Plants: Others	Total Thermal	Hydro-electric	Nuclear	Total
1960	1,512	1,259	n.a.	2,771	1,886	-	4,657
1965				8,244	2,000	-	10,244
1966				9,747	2,010	-	11,757
1967				11,609	2,022	-	13,631
1968				14,146	1,305	-	15,451
1969				15,391	1,839	-	17,230
1970				17,361	2,152	-	19,513
1971				18,846	2,170	-	21,016
1972							22,300
1975							
1980†	13,200	22,300	n.a.	35,500	5,750	13,750	55,000
1990‡							110,000-120,000
2000†				56,000-66,000§	14,000	120,000-130,000	200,000

n.a. - not available

* Except as indicated in other footnotes, all data are from Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 1972, p. 77.

† Bulgarian estimates for 1980 are from Yu. N. Savenko and Ye. O. Steynganz, Energeticheskiy balsnd (Energy Balance), Pub. "Energia," Moscow 1971.

‡ Bulgarian estimates for 1990 are from United Nations, Proceedings of the Fourth International Conference, Geneva 6-16 September 1971, Peaceful Uses of Atomic Energy, Paper A/CONF. 49/P/009.

§ By difference, from Bulgarian estimates.

Table F-18

TYPES OF FUEL USED IN BULGARIAN THERMAL POWER STATIONS*
(Percent of Total, on Equivalent Fuel Basis)

Type of Fuel	1965	1967
Coal, hard and brown	6.1	14.2
Lignite	74.5	72.0
Fuel oil and other liquid fuels	19.4	13.8
Natural and manufactured gas	none	none

* Public station only. Approximately 82% of all electric energy in Bulgaria is generated in public stations.

Table F-19

FUEL CONSUMPTION IN PUBLIC THERMAL STATIONS IN BULGARIA
(Grams Coal Equivalent per Net kWh)

Year	(Grams Coal Equivalent/Net kWh)
1963	595
1965	550
1967	522

kWh annually will be available from hydroelectric development; the rest would have to be made up from thermal stations and nuclear power as well as from imports of electricity through further development of the COMECON "MIR" electric power grid. Even as early as 1980 the Bulgarians envisage that of the total electric energy demand, 85 percent will be supplied by nuclear stations and energy and fuels imports.

Bulgarian thermal power stations have, at present, very high heat rates (Table F-19). These rates are probably due to the use of small, inefficient stations and are likely to improve as newer and bigger stations are built with the help of the USSR.

Detailed historical data for electric power generation and fuel demand in Bulgaria are given in Tables F-20 and F-21, respectively.

2. Electric Power Generation in Czechoslovakia

Czechoslovakia ranks second in per capita production and consumption of electric power in the COMECON bloc. It generated 47,237 million kWh of electricity in 1971, 5.7 percent being accounted for by hydroelectric power. At present no power is being generated by nuclear plants; however, ambitious plans for its development are being made as is the case with all fuels-deficient Eastern Bloc satellites of the USSR.

The share of hydroelectricity in total power production has been steadily dropping. It accounted for about 10 percent of total generated power in 1960 and has dropped to the present level of 5.7 percent. No significant additions of installed hydroelectric capacity have been made in the intervening period, and none is being envisaged for the future. The costs of development of remaining hydroelectric potential are apparently prohibitive, and most of the new installed capacity is to be achieved by construction of nuclear and fossil fueled thermal power plants. It is estimated that about 46.5 percent of all

Table F-20

ELECTRIC GENERATING PLANTS IN BULGARIA

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	- 1975	1980	1985	1990
Capacity* (MW)																					
Industrial	Maximum Net						Installed Capacity														
Thermal	n.a.	n.a.	48	43	100	150	66	92	183	241	239	380	407	503	583	637	824				
Hydro	n.a.	n.a.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	n.a.	n.a.	48	43	100	150	66	92	183	241	239	380	407	503	583	637	824				
Public																					
Thermal	n.a.	n.a.	312	354	265	265	515	612	765	999	1,148	1,494	1,688	2,188	2,626	2,664	2,831				
Hydro	n.a.	n.a.	252	308	460	460	462	494	545	746	768	767	770	771	810	816	824				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	n.a.	n.a.	564	662	725	725	977	1,106	1,310	1,745	1,916	2,261	2,458	2,959	3,436	3,480	3,655				
Combined																					
Thermal	n.a.	n.a.	360	397	365	415	581	704	948	1,240	1,387	1,874	2,095	2,691	3,209	3,301	3,655				
Hydro	n.a.	n.a.	252	308	460	460	462	494	545	746	768	767	770	771	810	816	824				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	n.a.	n.a.	612	705	825	875	1,043	1,198	1,493	1,986	2,155	2,641	2,865	3,462	4,019	4,117	4,479	440	880	1,760	3,500
Production (Gross)(Million kWh)																					
Industrial	Net Production						Gross Production														
Thermal	131	135	142	151	n.a.	n.a.	209	267	571	1,112	1,343	1,839	2,241	2,321	2,682	3,106	3,570				
Hydro	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	131	138	142	151	n.a.	n.a.	209	267	571	1,112	1,343	1,839	2,241	2,321	2,682	3,106	3,570				
Public																					
Thermal	1,138	1,220	1,493	1,692	2,765	2,771	3,402	4,082	4,527	6,117	6,901	7,908	9,368	11,825	12,709	14,255	15,276				
Hydro	644	751	825	954	1,104	1,886	1,796	1,695	2,086	1,471	2,000	2,010	2,022	1,305	1,839	2,152	2,170				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,000	5,750	7,000	8,000
Total	1,782	1,971	2,318	2,646	3,869*	4,657*	5,198	5,777	6,613	7,588	8,901	9,918	11,390	13,130	14,548	16,407	17,450				
Combined																					
Thermal	1,269	1,355	1,635	1,843	2,765	2,771	3,611	4,349	5,098	7,229	8,244	9,747	11,609	14,148	15,391	17,361	18,846				
Hydro	644	754	825	954	1,104	1,886	1,796	1,695	2,086	1,471	2,000	2,010	2,022	1,305	1,839	2,152	2,170				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,000	5,750	7,000	8,000
Total	1,913	2,109	2,460	2,797	3,869	4,657	5,407	6,044	7,184	8,700	10,244	11,757	13,631	15,451	17,230	19,513	21,016	385	2,500	6,200	20,000

* Includes Industrial producers

Sources: For 1955-60 and 1971 United Nations Electric Energy Statistics for Europe (1959, 1961, and 1971 editions).
For 1961 to 1970. United Nations Series J (No. 15, 1961-1970)

Table F-21

FUEL DEMAND IN ELECTRIC POWER GENERATION IN BULGARIA
(Thousand Tons of Coal Equivalent)

Fuel	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal			Public		Public and Private							Public					
Hard coal	n.a.	n.a.	941	727	877	869	853	n.a.	n.a.	n.a.	n.a.	993	n.a.	n.a.	n.a.	n.a.	n.a.
Brown coal				274	600	607	946					1,663					
Total coal			941	1,001	1,477	1,476	1,789					2.656					
Liquid fuels			33	28	54	58	61					469					
Natural gas			-	-	-	-	-					n.a.					
Manufactured gas (gas works)			-	3	-	-	-					n.a.					
Other fuels			-	-	-	-	-					n.a.					
Total fuels			974	1,032	1,531	1,534	1,860					3,125					
Grams coal equivalent/kWh production (gross)			580	529	554	554	515					395					
UN data*			591	543	n.a.	n.a.	n.a.					402					

n.a. - not available
Note: The private section (auto producers) shows up only in hard coal usage.

* Based on net production.

Source: UN, Annual Bulletin of Electric Energy Statistics for Europe, T-4.

economically developable hydroelectric potential is being utilized now. Generation of electric power by type of stations is shown in Table F-22.

As in other Soviet satellite countries, thermal stations, fueled by low grades of coal, account for the bulk of electric power generating capacity. The relative share of fuel types used in Czechoslovak thermal stations is shown in Table F-23, and fuel consumption in Table F-24. Low grade coals are expected to remain the principal fuel for thermal stations at least through 1990. Approximately 71 percent of all brown coal produced in Czechoslovakia in 1960 was used for production of electricity and heat as steam and hot water. This number rose to 77.5 percent in 1970 and is expected to be 87.0 percent in 1980 and 90 percent in 1990.[7] The Czechs expect the total amount of hard coal used in electric stations to decline somewhat by 1990 and remain constant after this date, while brown coal usage is to grow rapidly to approximately 28 million tons of coal equivalent by 1990 and then decline as nuclear capacity is brought on-stream (see Figure F-9).

As in other Eastern European countries, a significant portion of thermal power stations produce heat in the form of steam and hot water for industrial and space heating as well as electricity. Of all the heat used in industry and in the residential and commercial sectors in 1965, 40 percent was supplied by electric power stations. Heat production in electric stations is likely to grow further in the future as it leads to more efficient overall fuel utilization. Peaking capacity will probably be satisfied by installation of gas turbines with approximately 36 MW capacity of the type that Fiat manufactures, as well as by imports of electric energy from the USSR.

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[7] Proceedings of the Fourth International Conference, United Nations, Geneva, 6-16 September 1971, Peaceful Uses of Atomic Energy, Paper A/CONF. 49/P/009.

Table F-22

GENERATION OF ELECTRIC POWER IN CZECHOSLOVAKIA
BY TYPES OF POWER STATIONS*
(Million kWh)

Year	Thermal Plants	Hydroelectric	Nuclear	Total
1960	21,955	2,495	-	24,450
1965	29,734	4,456	-	34,190
1966	32,237	4,237	-	36,474
1967	34,900	3,714	-	38,614
1968	38,498	3,136	-	41,634
1969	40,639	2,496	-	43,134
1970	41,493	3,670	-	45,164
1971	44,553	2,684	-	47,237
1972				51,400
1975				63,000†
1980		2,900‡		97,000§
1990		2,900‡		184,000§
2000				345,000§

* Except as indicated in other footnotes, all data are from Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 197_ p. 77.

† Czech plan for 1975, Voprosy ekonomiki, No. 5, 1972, p. 79.

‡ SRI estimate based on Voprosy ekonomiki, No. 5, 1972, p. 52.

§ Czech estimates of consumption. They include projected imports of electric energy.

Table F-23

TYPES OF FUEL USED IN CZECHOSLOVAK THERMAL POWER STATIONS
(% of Total; on Equivalent Fuel Basis)

Type of Fuel	1965	1967
Hard coal	12.8	19.0
Brown coal	11.7	9.0
Lignite	63.7	60.4
Fuel oil and other liquid fuels	0.4	0.7
National and manufactured gas	0.9	0.7
Other fuels	10.5	10.2

* Public stations only. Approximately 78% of all electric energy in Czechoslovakia is generated in public stations.

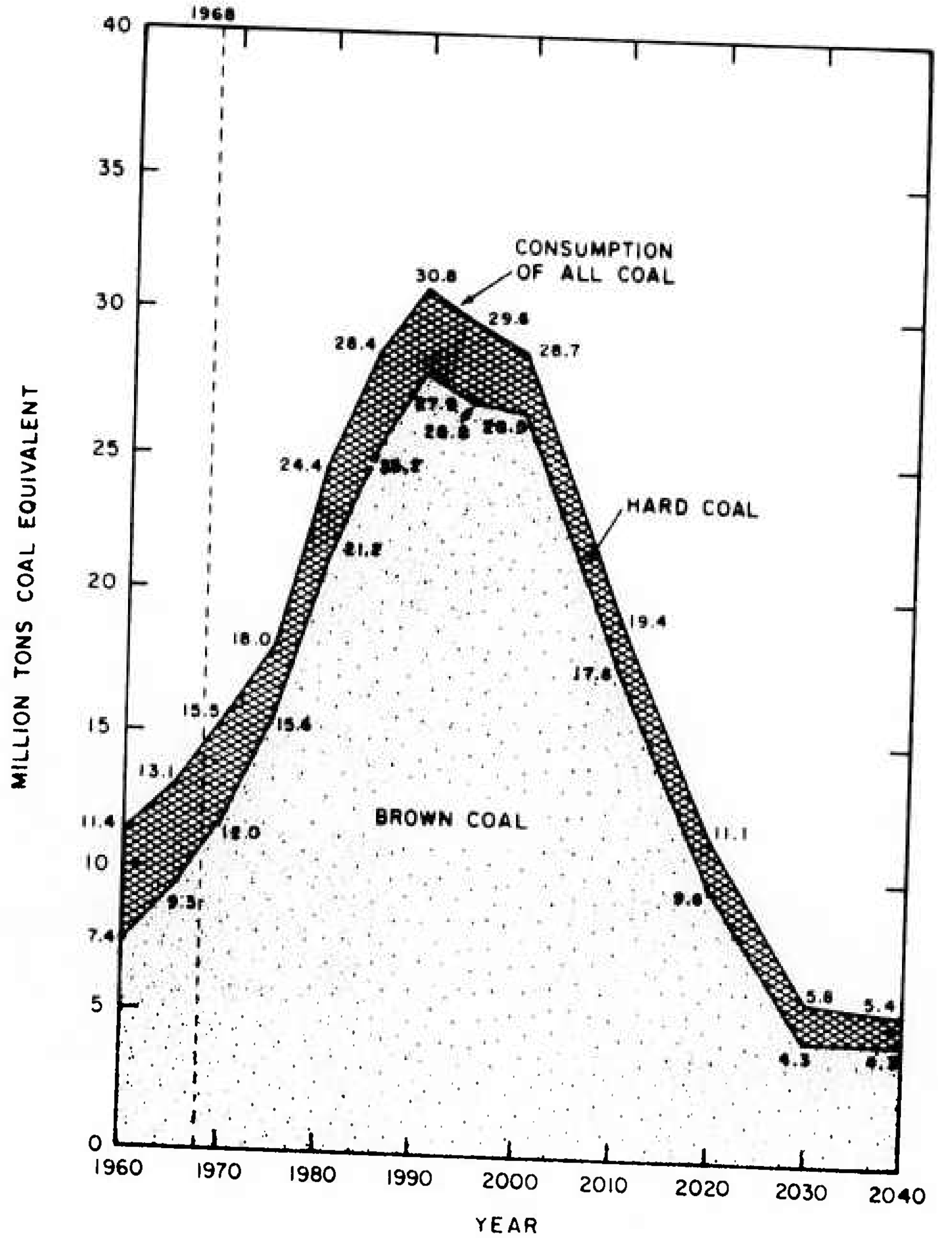
Source: Yu. N. Savenko and Ye. O. Steynganz, Energeticheskiy baland (Energy Balance), Pub. "Energia," Moscow 1971.

Table F-24

FUEL CONSUMPTION IN PUBLIC THERMAL STATIONS IN CZECHOSLOVAKIA
(Grams Coal Equivalent per kWh)

Year	Grams per net kWh	Grams per gross kWh
1963	534	
1965	500	
1967	468	426
1969		417

Sources: For grams per net kWh, Yu. N. Savenko and Ye. O. Steynganz, Energeticheskiy baland (Energy Balance), Pub. "Energia," Moscow 1971. For grams per gross kWh, Statistical Yearbook of the Czechoslovak Socialist Republic 1970, Prague 1970.



Source: United Nations, Proceedings of the Fourth International Conference, Geneva, 6 - 16 September 1971, Peaceful Uses of Atomic Energy, Paper A/CONF. 49/P/541.

Figure F - 9

ESTIMATES OF COAL CONSUMPTION FOR GENERATION OF ELECTRIC POWER IN CZECHOSLOVAKIA

The interconnection of electric grids of the COMECON countries has allowed electric energy to be exported by the USSR through Romania into Czechoslovakia. The export has been made possible by the installation of a 400/200 kV substation at Mukachevo (Ukranian SSR) in 1964 and the building of 220 kV transmission lines. At present, consideration is being given to construction of 750 kV transmission lines to tie in the various grids of the COMECON countries.

Detailed historical data for electric power generation and fuel demand in Czechoslovakia are given in Tables F-25 and F-26, respectively.

3. Electric Power Generation in East Germany

East Germany ranks first in consumption and production of electric power in the COMECON bloc. In 1970, East Germany generated 67,650 million kWh of electricity, of which nuclear power supplied approximately 0.7 percent and hydroelectric power supplied 1.8 percent of the total. Most of the near-term future growth of generating capacity will be accounted for by thermal stations burning brown coal, and the rest, by nuclear power. Table F-27 shows the generation of electric power by type of station.

The share of hydroelectric power is insignificant, with future generation of electric power from these sources likely to remain at the present level of about 1,250 million kWh per year. It has been estimated that approximately 80 percent of the hydroelectric potential is being used at present in East Germany. The reported production of hydroelectric power, however, is significantly higher than the estimated economically developable resources. This higher level is explained by the fact that a significant portion of this power is generated by the pumped storage facilities. In 1967, these facilities accounted for [illegible]

Table [illegible]

[illegible]CTRIC GENERATING PLANTS IN CZECHOSLOVAKIA

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1980	1985	1990
Capacity (MW)																				
	Maximum Net						Installed Capacity										Max. Net			
Industrial																				
Thermal	[illegible]	[illegible]	1,580	1.524	1,649	1,702	1,733	1,848	1,968	2,027	2,120	2,122	2,236	2,291	2,293	2,495	2,039			
Hydro	[illegible]	78	86	76	74	71	52	52	50	58	48	50	43	45	43	40	29			
Nuclear			-	-		-	-	-	-	-	-	-	-	-	-	-				
Total	[illegible]	[illegible]	1,666	[illegible]	1,723	1,773	1,785	1,900	2,018	2,082	2,168	2,172	2,279	2,336	2,336	2,535	2,068			
Public																				
Thermal	2,044	[illegible]	2,231	2,336	2,893	3,068	3,376	3,560	3,847	4,569	4,546	5,482	5,854	6,280	6,323	6,771	7,486			
Hydro	536	566	634	669	815	874	1,211	1,325	1,422	1,458	[illegible]	1,495	1,496	1,495	1,503	1,502	1,419			
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total	[illegible]	2,712	2,865	3,005	3,708	3,942	4,587	4,885	5,269	6,027	6,038	6,977	7,350	7,775	7,826	8,273	8,905			
Combined																				
Thermal	[illegible]	3,566	3,811	3,860	4,542	4,770	5,109	5,408	5,815	6,596	6,666	7,604	8,090	8,571	8,616	9,266	9,525			
Hydro	607	644	720	745	889	945	1,263	1,377	1,472	1,513	1,540	1,545	1,539	1,540	1,546	1,542	1,448			
Nuclear		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total	[illegible]	[illegible]	4,531	4,605	5,431	5,715	6,372	6,785	7,287	8,109	8,206	9,149	9,629	10,111	10,162	10,808	10,973	1,760	3,600	6,000
Production (Million kWh)																				
	Net Production						Gross Production													
Industrial																				
Thermal	4,486	4,739	4,595	5,006	5,546	5,460	6,367	6,597	7,104	7,567	7,950	8,162	8,831	9,227	9,265	9,284	9,868			
Hydro	291	262	274	300	192	227	218	199	193	181	196	165	128	120	095	112	105			
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total	4,777	5,001	4,869	5,306	5,738	5,687	6,585	6,796	7,297	7,748	8,146	8,327	8,959	9,347	9,360	9,396	9,973			
Public																				
Thermal	8,616	9,959	9,771	10,640	12,896	14,659	18,071	19,128	20,468	21,689	21,784	24,075	26,074	29,271	31,373	32,209	34,685			
Hydro	1,641	1,641	1,811	2,299	1,834	2,252	2,306	2,808	2,096	2,546	4,260	4,072	3,589	3,016	2,401	3,558	2,579			
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total	10,257	11,600	11,582	12,939	14,730	16,911	20,377	21,936	22,564	24,235	26,044	28,147	29,663	32,287	33,774	35,767	37,264			
Combined																				
Thermal	[illegible]	14,698	14,366	15,646	18,442	20,119	24,438	25,725	27,572	29,256	29,734	32,237	34,905	38,498	40,638	41,493	44,553			
Hydro	1,932	1,903	2,085	2,599	2,026	2,479	2,524	3,007	2,289	2,727	4,456	4,237	3,717	3,136	2,496	3,670	2,684	2,900	2,900	2,900
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,000	12,600	28,000
Total	[illegible]	16,601	16,451	18,245	20,468	22,598	26,962	28,732	29,861	31,983	34,190	36,474	38,622	41,634	43,134	45,163	47,237			

Sources: F[illegible] 1955[illegible] and [illegible] United Nations Electric Energy Statistics for Europe (1959, 1961 and 1971 [illegible])
Fo[illegible] 1961 to 19[illegible] [illegible]ted Nations Series J (No. 15, 1961 70)

Table F-28

FUEL DEMAND IN ELECTRIC POWER GENERATION IN CZECHOSLOVAKIA
(Thousand Tons of Coal Equivalent)

Fuel	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal																	
Hard coal	3,015	3,341	3,073	2,970	3,460	3,496	3,690	3,487	3,495	3,393	3,443	3,742	4,077	4,222	4,207	4,218	4,496
Brown coal	3,844	4,303	4,737	5,028	5,636	6,836	7,080	7,854	8,472	8,726	8,344	8,541	8,599	9,792	10,443	10,818	11,522
Total coal	6,859	7,644	7,810	7,998	9,096	10,332	10,770	11,341	11,967	12,119	11,787	12,283	12,676	14,014	14,650	15,036	16,018
Liquid fuels	9	11	12	43	22	32	89	134	177	242	240*	266	396	340	455	488	585
Natural gas*	78	165	420	792	832	670	551	228	173	155	77	68	53	125	227	183	194
Manufactured gas (gas works, coke-oven)	235	218	286	234	304	292	264	149	108	116	122	138	137	138	133	128	142
Other fuels (peat, blast furnace gas, waste)	32†	28†	596	682	652	45	746	995	1,120	1,134	1,189	1,271	1,251	1,197	1,184	1,109	1,12[illegible]
Total fuels	7,213	8,066	9,124	9,749	10,906	11,371	12,420	12,847	13,543	13,786	13,415	14,028	14,513	15,814	18,849	16,944	18,067
Grams coal equivalent/kWh production (gross)	552					518	508				451	435	418	411	410	408	406
UN data‡						523	549				490	473	454	448	445	447	443

* Based on "Supply and Demand of Natural Gas" Table (cu. meters × 1.18 = 10^3 t.c.e.) for years 1964-71. Years 1955-63 are from UN Electric Energy Statistics for Europe (tcal ÷ 7 = t.c.e.)

† Peat and fuelwood included under brown coal.

‡ Based on net production.

Source: UN Annual Bulletin of Electric Energy Statistics for Europe, T-4, p. 69.

Table F-27

GENERATION OF ELECTRIC POWER IN EAST GERMANY
BY TYPE OF POWER STATION
(Million kWh)

Year	Thermal Plants	Hydroelectric	Nuclear	Total
1960	39,688	617	-	40,305
1965	52,826	785	-	53,611
1966	55,816	1,050	96	56,866
1967	58,626	1,060	326	59,686
1968	61,908	1,197	392	63,230
1969	63,828	1,244	425	65,463
1970	66,052	1,251	464	67,650
1971	68,169	1,251	404	69,420
1972				72,800
1975		1,250*		88,000-† 9,000
1980				
1990		1,250*		
2000				275,000‡

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* SRI estimates.

† Official East German five-year plan estimate.

‡ East German estimate, Voprosy ekonomiki, No. 5, 1972, p. 79.

Source: Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 1972, p. 77.

million kWh of the total 1,060 million kWh reported for all hydroelectric production.

Like other countries of Eastern Europe, East Germany produces steam and hot water in a significant portion of its thermal stations for distribution to consumers. In order to lower fuel consumption, East Germans have built boilers of capacities close to 420 tons per hour of steam fueled by brown coal of very low quality (1,700 Kcal/kg). Steam turbogenerators of 100 MW size have been available from local manufacturers since 1961 and these have been used in combined heat/power stations together with boilers of high steam throughput.

Table F-28 shows the types of fuels used by public thermal stations. Lignite is still the predominant fuel and is likely to remain so at least until 1980. The use of low quality fuels such as lignite is probably responsible for the high heat rates of public thermal stations, as can be seen in Table F-29. The specific fuel use is expected to decrease, however, with the current construction of large thermal stations having large turbogenerators. Turbogenerators of 500 MW capacities and critical steam parameters imported from the USSR are being installed at present. During the current five-year plan, East Germany plans to expand its installed electric generating capacity by 5,900 to 6,400 MW. Sixty percent of this capacity is to be fueled by brown coal, 14 percent (880 MW) is to be accounted for by nuclear power, and 16 percent by small peak demand plants using gas and fuel oil. The electric energy production should reach 88 to 90 million kWh by 1975.

The long-range East German plans call for production of up to 275 billion kWh by the year 2000. Presumably most of this is to be made up by nuclear power generation.

Detailed historical data for electric power generation and fuel demand in East Germany are given in Tables F-30 and F-31, respectively.

Table F-28

TYPES OF FUEL USED IN EAST GERMAN THERMAL POWER STATIONS*
(Percent of Total, on Equivalent Fuel Basis)

Type of Fuel	1965	1967
Hard coal	4.3%	3.5%
Lignite (including brown coal)	93.6	93.8
Fuel oil and other liquid fuels	1.8	2.6
Natural and manufactured gas	0.3	0.1
Other fuels	0.3	-

* Public stations only. Approximately 72% of all thermal electric power in East Germany is generated by public stations.

Table F-29

FUEL CONSUMPTION IN PUBLIC THERMAL STATIONS IN EAST GERMANY
(Grams Coal Equivalent per Net kWh)

Year	Grams Coal Equivalent/kWh
1963	613
1965	557
1967	510

Table F-30

ELECTRIC GENERATING PLANTS IN EAST GERMANY

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Capacity (MW)										
Industrial	Maximum Net									
Thermal	2,832	2,966	2,968	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	50	50	42	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	2,882	3,016	3,010	n.a.	n.a.	n.a.	4,017	4,039	4,007	4,180
Public										
Thermal	2,111	2,326	2,377	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	86	87	129	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	2,197	2,413	2,506	n.a.	n.a.	n.a.	4,312	4,388	4,887	5,424
Combined										
Thermal	4,943	5,292	5,345	6,770	7,238	7,842	8,003	8,104	8,574	9,290
Hydro	136	137	171	n.a.	n.a.	n.a.	326	323	320	314
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	5,079	5,429	5,516	n.a.	n.a.	n.a.	8,329	8,427	8,894	9,604
Production (Million kWh)										
Industrial									Gross Production	
Thermal	16,850	17,720	18,380	19,020	19,010	19,420	20,367	21,127	21,585	22,512
Hydro	170	150	130	170	110	130	141	126	60	59
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	17,020	17,870	18,510	19,190	19,120	19,550	20,508	21,253	21,645	22,571
Public										
Thermal	11,340	12,940	13,870	15,210	17,700	20,260	21,472	23,325	25,318	27,984
Hydro	330	370	350	470	430	490	535	485	487	477
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	11,670	13,310	14,220	15,680	18,130	20,750	22,007	23,810	25,805	28,461
Combined										
Thermal	28,190	30,660	32,250	34,230	36,710	39,680	41,839	44,452	46,903	50,496
Hydro	500	520	480	640	540	620	676	611	547	536
Nuclear	-	-	-	-	-	-	-	-	-	-
Total	28,690	31,180	32,730	34,870	37,250	40,300	42,515	45,063	47,450	51,032

Capacity and Production	1965	1966	1967	1968	1969	1970	1971	1975	1980	1985	1990
Capacity (MW)											
Industrial			Maximum Net								
Thermal	4,273	4,341	4,488	4,065	4,006	4,082	4,050				
Hydro	16	17	9	8	6	7	7				
Nuclear	-	-	-	-	-	-	-				
Total	4,289	4,358	4,497	4,073	4,012	4,089	4,057				
Public											
Thermal	5,645	6,069	6,336	6,161	6,446	7,257	8,001				
Hydro	416	570	614	649	646	646	645				
Nuclear	-	70	75	75	75	75	75				
Total	6,061	6,709	7,025	6,885	7,167	7,978	8,721				
Combined											
Thermal	9,918	10,410	10,824	10,226	10,452	11,339	12,051				
Hydro	432	587	623	657	652	653	652				
Nuclear	-	70	75	75	75	75	75	510	2,000	4,000	7,000
Total	10,350	11,067	11,522	11,673	11,910	12,669	12,778				
Production (Million kWh)											
Industrial	Gross Production										
Thermal	22,187	22,364	23,060	24,563	25,520	25,381	25,053				
Hydro	87	90	90	97	93	52	49				
Nuclear	-	-	-	-	-	-	-				
Total	22,274	22,454	23,150	24,660	25,613	25,433	25,102				
Public											
Thermal	30,639	33,356	35,240	37,078	38,275	40,554	42,747				
Hydro	698	960	970	1,100	1,150	1,199	1,168				
Nuclear	-	96	326	392	425	464	404				
Total	31,337	34,412	36,536	38,570	39,850	42,217	44,319				
Combined											
Thermal	52,826	55,720	58,300	61,641	63,795	65,935	67,800				
Hydro	785	1,050	1,060	1,197	1,243	1,251	1,217	1,250	1,250	1,250	1,250
Nuclear	-	96	326	392	425	464	404	2,100	11,000	23,000	42,000
Total	53,611	56,866	59,686	63,230	65,463	67,650	69,421				

n.a. - not available.

Sources: For 1955-60 and 1971: UN Electric Energy Statistics for Europe (1959, 1961, and 1971 editions). For 1961 to 1970: UN Series J (No. 15, 1961-1970).

Table I-31

FUEL DEMAND IN ELECTRIC POWER GENERATION IN EAST GERMANY
(Thousand Tons of Coal Equivalent)

Fuel	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal																	
Hard coal	n.a.	5,064	4,771					n.a.	n.a.	n.a.	820	1,066	918	791	775	548	646
Brown coal		11,829	12,729								22,757	40,697	40,259	42,225	44,011	26,640	26,574
Total coal		16,893	17,500								23,577	41,763	41,177	43,016	44,786	27,188	27,220
Liquid fuels		14	13								505	1,282	1,382	1,796	2,014	992	992
Natural gas		-	-								-	n.a.	n.a.	34	137	363	713
Manufactured gas (gas works)		771	857								1,072	-	-	-	-	-	-
Other fuels (peat, blast furnace gas, waste)		-	-								69	1,738	1,782	1,532	1,372	608	709
Total fuels		17,678	18,370								25,224	44,783	44,341	46,378	48,309	29,151	29,634
Grams coal equivalent/kWh production (gross)		577	570								478	804	761	752	757	442	437
UN data*		n.a.	n.a.								481	460	440	435	441	442	437

* Based on net calorific value/gross production.

Source: UN Annual Bulletin of Electric Energy Statistics for Europe, T-4.

4. Electric Power Generation in Hungary

Hungary has the distinction of being the smallest per capita producer and consumer of electric power in Eastern Europe. It generated 14,542 million kWh of electricity in 1970 and imported approximately 19 percent of the power it consumed. Of the power it generated internally, only 0.6 percent was contributed by hydroelectricity. The rest was generated by thermal stations using mostly lignite. The Hungarians are considering the construction of nuclear plants in the future, but at present no definite plans have been revealed as to when such construction might begin. The present five-year plan (1971-1975) calls for the expansion of electric power based on construction of new thermal plants, and this is likely to be the approach, for the near future as well, probably at least through 1980.

Hydroelectric power is insignificant in terms of installed or generating capacity at present, as can be seen from Table F-32, which shows the generation of electric power by type of power station. Although only about 2 percent of the estimated economically developable hydroelectric resources are at present utilized, no definite plans exist for expansion of this capacity in the near future.

As in other Eastern European countries, electric power capacity was expanded in the period 1966 to 1970 with the introduction of 200 MW turbogenerators of Soviet manufacture, working on supercritical steam. It is likely that Hungary will continue to depend on Soviet equipment in the future, with the 500 MW turbogenerator being responsible for most of its future capacity growth.

The thermal stations still depend heavily on low grade coal (lignite) for their fuel (Table F-33). However, with the planned reconstruction of their fuels base, most of the newly installed thermal power plants will be fueled by Soviet natural gas and fuel oil. At present,

Table F-32

GENERATION OF ELECTRIC POWER IN HUNGARY BY TYPES OF POWER STATIONS
(Million kWh)

Year	Thermal Plants	Hydroelectric	Nuclear	Total
1960	7,524	93	-	7,617
1965	11,102	75	-	11,177
1966	11,762	99	-	11,861
1967	12,409	81	-	12,490
1968	13,066	89	-	13,155
1969	13,973	96	-	14,069
1970	14,454	88	-	14,542
1971	14,896	94	-	14,990
1972	n.e.		-	16,300
1975	n.e.	100*	-	21,000-22,000†

n.e. - not estimated.

* SRI estimate.

† Hungarian five-year plan estimates.

Source: Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 1972, p. 77.

Table F-33

TYPES OF FUEL USED IN HUNGARIAN THERMAL POWER STATIONS*
(Percent of Total, on Equivalent Fuel Basis)

Type of Fuel	1965	1967	1969	1970
Brown coal	8.7	11.5	65	66
Lignite	73.1	66.1		
Fuel oil and other petroleum liquid fuels	12.6	13.5	35	34
Natural gas	5.6	8.9		

* Public stations only. Approximately 93% of all power generated in thermal stations is in public stations.

Hungary imports its natural gas from Romania, but by 1975 significant quantities are expected to arrive from the USSR. It is expected that by 1975 at least 43 percent of Hungary's energy will be imported. The specific consumption of fuel (heat rate) is still fairly high in Hungarian thermal stations, but these rates are declining with the introduction of new equipment. Representative heat rates for thermal stations in the public sector can be seen in Table F-34.

Hungary will continue to depend heavily on electric power imports from its neighbors. There is at present a 400 kV line interconnecting the southweatern Soviet grid from the substation at Mukachevo with the Hungarian power grid. Installation of 750 kV transmission lines are being planned.

Table F-34

FUEL CONSUMPTION IN PUBLIC THERMAL STATIONS IN HUNGARY
(Grams Coal Equivalent per Net kWh)

Year	Grams Coal Equivalent/Net kWh
1963	536
1965	510
1967	492
1969	453
1970	452

Detailed historical data for electric power generation and fuel demand in Hungary are given in Tables F-35 and F-36, respectively.

5. Electric Power Generation in Poland

Poland is in a more fortunate position with its fuel resources than other Soviet satellite countries. Its coal resources seem to be more than adequate to supply the electric energy demands well into the 1970s, although plans are being made to expand the hydroelectric power production as well as to install some nuclear capacity by 1985. In 1970 Poland generated some 64,500 million kWh of electricity, of which hydropower accounted for only 2.9 percent of the total. It is now self-sufficient in electric power and could possibly generate enough again for net export as it has done in the past. Because of this self-sufficiency in coal resources, it does not plan to introduce nuclear

Table F-35

ELECTRIC GENERATING PLANTS IN HUNGARY

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1975	1980	1985	1990
Capacity (MW)																					
	Maximum Net						Installed Capacity										Max. Net				
Industrial																					
Thermal	n.a.	175	169	169	176	180	315	322	313	332	333	347	342	347	371	365	335				
Hydro	n.a.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	n.a.	175	169	169	176	180	315	322	313	332	333	347	342	347	371	365	335				
Public																					
Thermal	n.a.	797	878	962	1.026	1.100	1.241	1.306	1.452	1.555	1.644	1.639	1,697	2.233	2.179	2.348	2.284				
Hydro	n.a.	8	11	15	17	18	19	19	20	21	21	21	21	21	20	20	20				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	n.a.	805	889	977	1.043	1.118	1.260	1.325	1.472	1.576	1.665	1.660	1.718	2.254	2.199	2,368	2.304				
Combined																					
Thermal	n.a.	972	1.047	1.131	1.202	1.280	1.556	1.628	1.765	1.887	1.977	1.986	2.039	2.580	2.550	2.713	2.619				
Hydro	n.a.	8	11	15	17	18	19	19	20	21	21	21	21	21	20	20	20				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	440	880	1.760
Total	n.a.	980	1.058	1.146	1.219	1.298	1.575	1.647	1.785	1.908	1.998	2.007	2.060	2.601	2.570	2.733	2.639				
Production (Million kWh)																					
	Net Production						Gross Production														
Industrial																					
Thermal	1,054	956	918	980	1.018	999	1.177	1.215	1,179	1,201	1.230	1.280	1.299	1.157	1.211	1.151	1,090				
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	1.054	958	918	980	1.018	999	1.177	1.215	1,179	1.201	1,230	1.280	1,299	1.157	1.211	1.151	1.090				
Public																					
Thermal	3,843	3.710	3.976	4.850	5.346	5.825	7,123	7.822	8.405	9,305	9,872	10.481	11,109	11,909	12.763	13.298	13,806				
Hydro	45	35	41	47	77	91	82	82	81	74	75	100	82	89	95	88	94	100	100	100	100
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	3.888	3.745	4.017	4.897	5.423	5.916	7.205	7.904	8.486	9.379	9.947	10,581	11.191	11,998	12.858	13,386	13.990				
Combined																					
Thermal	4,897	4,668	4,894	5,830	6,364	6,824	8,300	9,037	9,584	10,506	11,102	11,761	12,408	13,066	13,974	14,449	14,896				
Hydro	45	35	41	47	77	91	82	82	81	74	75	100	82	89	95	88	94	100	100	100	100
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	480	2,000	7,000
Total	4,942	4,703	4,935	5,877	6,441	6.915	8,382	9,119	9,665	10,580	11.177	11,861	12,490	13,155	14,069	14,537	14,990				

n.a. - Not available.

Sources: For 1955-60 and 1971: UN Electric Energy Statistics for Europe (1959, 1961, and 1971 editions).
For 1961 to 1970: UN Series J (No. 15, 1961-70).

Table F-36

FUEL DEMAND IN ELECTRIC POWER GENERATION IN HUNGARY
(Thousand Tons of Coal Equivalent)

Fuel	1955	1958	1957	1958	1959	1960	1981	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal																	
Hard coal	n.a.	n.a.	1,701	2,326	2,391	2,633	2,766	542	534	594	591	800	641	878*	850*	823*	850*
Brown coal	n.a.	n.a.	930	723	738	836	843	4,102	4,158	4,253	4,357	4,219	4,264	3,814*	3,898*	4,211*	4,481*
Total coal	n.a.	n.a.	3,102	3,670	3,700	4,065	4,245	4,644	4,892	4,847	4,948	5,019	5,205	4,692	4,748	5,034	5,331
Liquid fuels	n.a.	n.a.	71	74	82	133	236	262	344	660	755	857	807	853*	1,072*	1,321*	1,560*
Natural gas†	-	-	-	-	100	101	109	111	189	191	286	531	758	1,132	1,290	1,097	916
Manufactured gas (coke-only and gas works)	-	-	118‡	273‡	142‡	132‡	139‡	7	8	12	13	10	18	41	26	15	14
Other fuels (blast furnace gas, waste)	-	-	1	-	2	2	2	101	87	92	95	202	222	217	239	217	111
Total	n.a.	n.a.	3,292	4,017	4,026	4,433	4,731	5,127	5,320	5,802	8,097	6,619	6,910	6,935	7,375	7,684	7,932
Grams coal equivalent/kWh production (gross)			809	625	574	589	570	567	555	552	549	563	557	531	528	532	533
UN data§			578	558	542	541					513	505	494				

n.a. - not available.

* Estimated or only partly known.

† Natural gas data from "Supply and Demand of Natural Gas" Table (cu. meters × 1.18 = 10^3 t.c.e.)

‡ Includes blast furnace gas.

§ Based on net calorific value/semi-net production.

Sources: UN Annual Bulletin of Electric Energy Statistics for Europe, T-4 (tcal ÷ 7 = t.c.e.).
UN Annual Bulletin of General Energy Statistics for Europe, T-2.

power as fast as other Eastern Bloc Soviet satellites. Table F-37 shows the generation of electric power in Poland by type of station.

The Poles plan to keep the relative share of hydroelectric power in the future at the present level of about 2.9 percent of total power. It is estimated that the utilization of hydroelectricity has reached 17 percent of economically developable hydroelectric capacity in 1967. Further, additional capacity indicated in Polish plans are to be mainly of the pumped storage type facilities, presumably for peak load coverage.

The thermal power plants are currently responsible for most electric power generation and are likely to remain in this position at least through 1990. Unlike other Eastern European countries, Poland plans to reduce the proportion of electricity generated in plants supplying both heat and power, with the greatest portion of new capacity to be installed in condensing type steam turbines. Most of the newly installed capacity is to be fueled by brown coal exclusively. The use of brown coal is planned to be phased out and replaced by oil and gas in other sectors. With the projected drop in specific consumption of fuel in power plants, some increase in production, and diversion from other consuming sectors, the availability of brown coal should satisfy power plant demands in the future. Tables F-38 and F-39 show fuel type usage and specific fuel consumption (heat rates) of the public thermal stations in Poland. Some planners in Poland feel that the projected demands in electric energy will require installation of nuclear plants beyond 1980 because of a possible deficit in brown coal production if the predicted industrial growth materializes. With the possibility of using conventional, coal-fired generators in conjunction with nuclear reactors, Poland is now designing turbogenerators of 500 MW size for subcritical steam. The units of 125 MW and 200 MW capacity have also been designed to operate in the subcritical region. Both of these units

Table F-37

GENERATION OF ELECTRIC POWER IN POLAND BY TYPE OF POWER STATION*
(Million kWh)

Year	Thermal Plants† Steam Heat/Power	Thermal Plants† Steam Condensing	Thermal Plants† Others	Total Thermal	Hydro-electric	Nuclear	Total
1960	8,423	20,225	n.a.	28,648	659	-	29,307
1965	6,004‡	36,884	n.a.	42,888	913	-	43,801
1966				46,456	929	-	47,385
1967				50,263	994	-	51,257
1968				54,465	1,055	-	55,520
1969				59,145	908	-	60,053
1970				62,645	1,887	-	64,532
1971				67,939	1,927	-	69,866
1972						-	76,400
1975					2,500§	-	95,000§
1980	4,320§	126,630§	n.a.	130,950	3,645§	405§	135,000§
1985					5,500§	3,000-10,000§	190,000§
1990							270,000§

n.a. - not available.

* Except as indicated in the other footnotes, all data are from Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 1972, p. 77.

† Data from Yu. N. Savenko and Ye. O. Steynganz, Energeticheskiy baland (Energy Balance), Pub. "Energia," Moscow 1971.

‡ From Energetika Mira (World Energy), Pub. "Energia," Moscow 1970, (Reports of the VIIth World Energy Conference in Moscow, 1968), p. 126.

§ Polish estimates (see Savenko and Steynganz, and Energetika Mira, above). These estimates do not include possible production of power for export.

Table F-38

TYPES OF FUEL USED IN POLISH THERMAL POWER STATIONS*
(Percent of Total, on Equivalent Fuel Basis)

Type of Fuel	1965	1967
Hard coal	39.0%	41.9%
Brown coal	30.8	26.4
Lignite	28.3	30.7
Liquid fuels	0.7	0.7
Natural and manufactured gas	1.2	0.3

* Public station only. Approximately 87% of all power generated in thermal stations is in public stations.

Table F-39

FUEL CONSUMPTION IN PUBLIC THERMAL STATIONS IN POLAND
(Grams Coal Equivalent per Net kWh)

Year	Grams Coal Equivalent/Net kWh
1963	482
1965	442
1967	435
1970	422
1971	419

are now being manufactured in Poland, although the 200 MW units had to be imported from USSR prior to 1967.

The largest thermal station operating in Poland at present has an installed capacity of 1,600 MW, with additional capacity under construction for an eventual aggregate capacity of 3,000 MW. Another 2,000 MW is currently under construction. Both of these stations are coal fueled. The first units of 500 MW capacity are planned to be in operation by 1976.

At present, Poland has a well-developed power grid consisting mainly of 400 and 220 kV transmission lines. Further expansion of this grid is planned, mainly with 400 and 110 kV lines.

Detailed historical data for electric power generation and fuel demand in Poland are given in Tables F-40 and F-41, respectively.

6. Electric Power Generation in Romania

Romania is the only other Soviet satellite, besides Poland, which is at present self-sufficient in fuels/energy resources. Even though Romania imports crude oil, it exports enough refined oil products to make for a favorable fuels trade balance. Although it is still low in per capita generation and consumption of electric energy, it has registered a spectacular growth rate in this regard and has moved from last place among the Eastern European satellite countries in 1960 to rank over Hungary and about equal to Poland and Bulgaria. The generating capacity of newly installed thermal stations accounted for most of this growth, although the hydroelectric installed capacity grew appreciably during this period as well. At present, no nuclear power is being generated in Romania, although plans are being made for such construction beyond 1975. Table F-42 shows the generation of electric power in Romania by type of station.

Table F-40

ELECTRIC GENERATING PLANTS IN POLAND

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1975	1980	1985	1990
Capacity (MW)																					
Industrial	Maximum Net						Installed Capacity										Max. Net				
Thermal	926	920	1,062	1,222	1,289	1,365	1,853	1,824	1,875	1,846	1,812	1,956	2,073	2,124	2,248	2,253	2,273				
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	926	920	1,062	1,222	1,289	1,365	1,853	1,824	1,875	1,846	1,812	1,956	2,073	2,124	2,248	2,253	2,273				
Public																					
Thermal	2,200	2,343	2,627	3,118	3,326	3,659	4,604	5,565	6,239	7,008	7,510	7,614	8,487	8,981	10,105	10,867	11,437				
Hydro	235	235	237	245	235	258	311	327	349	349	350	350	373	486	508	771	790				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	2,435	2,578	2,864	3,363	3,561	3,917	4,915	5,892	6,588	7,357	7,860	7,961	8,860	9,467	10,613	11,638	12,227				
Combined																					
Thermal	3,126	3,263	3,689	4,340	4,615	5,024	6,457	7,389	8,114	8,854	9,322	9,570	10,560	11,105	12,353	13,120	13,710				
Hydro	235	235	237	245	235	258	311	327	349	349	350	350	373	486	508	771	790				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	440	880
Total	3,361	3,498	3,926	4,585	4,850	5,282	6,768	7,716	8,463	9,203	9,672	9,920	10,933	11,591	12,861	13,891	14,500				
Production (Million kWh)																					
Industrial	Net Production						Gross Production														
Thermal	4,300	4,232	4,644	5,436	5,839	6,291	6,932	7,156	7,591	6,456	6,196	6,670	7,648	8,024	8,258	8,485	8,765				
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	4,300	4,232	4,644	5,436	5,839	6,291	6,932	7,156	7,591	6,456	6,196	6,670	7,648	8,024	8,258	8,485	8,765				
Public																					
Thermal	11,396	13,057	14,184	15,719	17,743	19,904	24,703	27,453	29,701	33,429	36,692	39,786	42,885	46,441	50,894	54,188	59,187				
Hydro	705	634	571	757	547	653	619	774	670	726	913	929	994	1,055	908	1,887	1,919				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	12,101	13,691	14,755	16,476	18,290	20,557	25,322	28,227	30,371	34,155	37,605	40,715	43,879	47,496	51,802	56,045	61,106				
Combined																					
Thermal	15,696	17,289	18,828	21,155	23,582	26,195	31,635	34,609	36,292	39,885	42,888	46,456	50,533	54,465	59,152	62,643	67,952				
Hydro	705	634	571	757	547	653	619	774	670	726	913	929	994	1,055	908	1,887	1,919	2,500	3,645	5,500	6,500
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,000	4,000
Total	16,401	17,923	19,399	21,912	24,129	26,848	32,254	35,383	36,962	40,611	43,801	47,385	51,527	55,520	60,060	64,530	69,871				

Sources: For 1955-60 and 1971: UN Electric Energy Statistics for Europe (1959, 1961, and 1971 editions).
For 1961 to 1970: UN Series J (No. 15 1961-1970).

Table F-41

FUEL DEMAND IN ELECTRIC POWER GENERATION IN POLAND
(Thousand Tons of Coal Equivalent)

Fuel	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal																	
Hard coal	10,286	10,576	11,321	11,942	12,396	13,339	13,925	14,381	13,877	12,778	12,574	13,159	14,548	14,409	14,586	14,960	16,086
Brown coal	141	96	108	290	614	651	843	1,147	1,992	3,342	4,272	4,992	5,456	6,168	7,295	7,699	8,198
Total coal	10,427	10,672	11,429	12,232	13,010	13,990	14,766	15,528	15,889	16,120	16,646	18,151	20,004	20,577	21,881	22,659	24,284
Liquid fuels	15	19	18	25	19	16	25	36	62	132	113	114	116	160	285	544	611
Natural gas*	-	-	-	-	-	34	217	258	255	393	275	139	72	163	825	1,966	920
Manufactured gas (gas works and coke-oven)	282†	323†	314†	277†	426†	309†	-	-	52	60	74	64	85	122	66	66	51
Other fuels (peat, wood, blast furnace gas, waste)	-	-	-	-	-	4	283‡	263‡	226	226	241	233	219	303	331	326	328
Total fuels	10,724	11,014	11,761	12,534	13,455	14,283	15,273	18,085	16,464	16,931	17,549	18,721	20,496	21,345	23,388	25,561	26,194
Grams coal equivalent/kWh production (gross)	829					498					409	403	422	392	395	408	386
UN data§	883					535					430	435	432	425	422	419	415

* Based on "Supply and Demand of Natural Gas" Table (cu. meters × 1.18 = 10^3 t.c.e.) for years 1960-71.

† Includes blast-furnace gas.

‡ Includes small quantities of manufactured gas.

§ Based on net calorific value for semi-net production.

Source: UN Annual Bulletin of Electric Energy Statistics for Europe, T-4, p. 83.

Table F-12

GENERATION OF ELECTRIC POWER IN ROMANIA BY TYPE OF POWER STATION
(Million kWh)

Year	Thermal Plants	Hydroelectric	Nuclear	Total
1960	7,253	397	-	7,650
1965	16,210	1,005	-	17,215
1966	19,771	1,035	-	20,806
1967	23,293	1,476	-	24,769
1968	26,266	1,562	-	27,828
1969	29,292	2,217	-	31,509
1970	32,315	2,773	-	35,088
1971	34,959	4,495	-	39,454
1972				43,400
1975		9,760		58,000-* 60,800
1980		12,000		80,000-* 85,000
1990		16,000		

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* Romanian estimates, Voprosy ekonomiki, No. 5, 1972, p. 79.

Source: Statisticheskiy ezhegodink stran-chlenov soveta ekonomicheskoi vzaimnopomoschi 1972 (COMECON Statistical Annual), Moscow 1972, p. 77

Among all of the Soviet Eastern European satellites, Romania possesses the highest economically developable hydroelectric potential. The share of hydroelectric power in the production of electricity had risen from approximately 5 percent in 1960 to 11 percent in 1971 of the total generated electric power. This increase was due to several accomplishments: completion in 1960 of the Lenin hydropower station at Bicaz on the River Bistritsa of 210 MW capacity; the construction in the period 1960-1966 of a hydroelectric station on the Argesh River of 220 MW capacity (four turbines of 55 MW each) and 12 small stations on the Lower Bicaz with an aggregate capacity of 240 MW; and the partial completion of the large "Iron Gates" station on the Danube of the projected capacity of 2,100 MW. The "Iron Gates" station is shared equally with Yugoslavia. The future plans call for further expansion of hydroelectric capacity. The Romanians plan to have 3,254 MW of total installed hydroelectric capacity by 1975. With the completion of the "Iron Gates" station and a 510 MW station, started in the late 1960s, this capacity will probably be achieved.

The dramatic restructuring of the fuels supply to electric stations in the past 15 years or so was required because of rapid growth in electric energy demand. Fuel oil and gas oil accounted for approximately 36 percent of all fuel supplied to thermal stations in 1958. The inability to increase oil production rapidly enough to satisfy growing demands required ever increasing supplies of natural gas to these stations. At the same time, as rail transport was shifted to diesel fuel, more coal became available for electric stations. These changes are reflected in Table F-43, which shows the fuel types used in thermal stations for selected years over a 15-year period.

Introduction of new larger turbogenerators and better accounting procedures in the electric industry have contributed to the lowering

Table F-43

TYPES OF FUEL USED IN ROMANIAN THERMAL POWER STATIONS
(Percent of Total, on Equivalent Fuel Basis)

	1955	1960	1965	1970	1971
Brown coal	13.2%	18.7%	16.0%	25.1%	25.6%
Hard coal	6.3	3.7	3.6	5.2	7.1
Gas oil	11.8	7.9	3.7	0.6	0.5
Fuel oil	23.9	5.2	1.8	2.7	2.5
Natural gas	41.7	63.6	74.2	63.5	62.2
Total*	100.0	100.0	100.0	100.0	100.0

* The five different totals are 0.7% to 3.1% short of 100%.

Source: Romanian Statistical Yearbook, Bucharest, 1971.

of the specific fuel consumption in thermal stations. During the 1955-1960 period, turbogenerators of 20, 25, and 50 MW were installed, as a rule, in Romanian thermal stations, whereas in succeeding years, generators of 100, 150, and 200 MW capacities were being installed. At present, 330 MW units are being installed as standard practice. Stations of 1,000-1,500 MW, working on supercritical steam, are being installed now. Table F-44 shows the average heat rates for Romanian thermal stations.

As in most other Eastern European COMECON countries, the production of steam and hot water in thermal stations, for distribution to consumers, is going to be increased. Production has grown from about 8.5 million gigacalories (Gcal) in 1960 to 25 million Gcal in 1966 and will probably reach 45 million Gcal by 1975, according to Romanian planners.

Table F-44

FUEL CONSUMPTION IN ROMANIAN THERMAL STATIONS
(Grams Coal Equivalent per Gross kWh)

	1955	1960	1965	1970	1971
Stations burning:					
Brown coal	759	538	486	370	372
Hard coal	948	680	425	389	351
Gas oil	445	420	436	392	365
Fuel oil	723	628	497	340	361
Natural gas	648	466	380	322	312
For all stations	723	502	407	341	333

Source: Romanian Statistical Yearbook, Bucharest, 1971.

Gas turbines will continue to be used for peak power generation as well as for emergency standby. Romania was the first to use these units among the Eastern European countries, with the first Fiat 36 MW unit coming on-stream at the Bucharest plant in 1966. Consideration is also being given to the use of aviation turbines for these purposes.

The electric power grid, which consists of 110-, 220-, and 400-kV lines, is tied in with those of the USSR, Czechoslovakia, Bulgaria, and Yugoslavia.

Nuclear power is unlikely to be prominent on the Romanian scene in the near future. The first commercial units are not likely to go into operation before 1980, although earlier plans called for installation of 1,000 MW nuclear capacity by 1975. There is no evidence

of this construction activity at present. However, the Romanians are laying a basis for nuclear power development with an experimental reactor at the Institute of Atomic Physics at Bucharest.

Detailed historical data for electric power generation and fuel demand in Romania are given in Tables F-45 and F-46, respectively.

Table F-45

ELECTRIC GENERATING PLANTS IN ROMANIA

Capacity and Production	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1975	1980	1985	1990
Capacity (MW)																					
Industrial								Installed Capacity													
Thermal	453	467	498	515	529	544	514	544	548	572	624	674	698	733	758	794	n.a.				
Hydro	40	40	40	40	40	40	30	30	28	28	27	26	30	30	29	29	n.a.				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	493	507	538	555	569	584	544	574	576	600	651	700	728	763	787	823	n.a.				
Public																					
Thermal	667	767	842	892	975	1,059	1,140	1,247	1,481	1,878	2,173	3,020	3,689	4,047	4,824	5,352	n.a.				
Hydro	67	67	67	67	67	178	179	278	299	388	434	751	781	801	821	1,171	n.a.				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	734	834	909	959	1,042	1,237	1,319	1,525	1,780	2,266	2,607	3,771	4,470	4,848	5,645	6,523	n.a.				
Combined																					
Thermal	1,120	1,234	1,340	1,407	1,504	1,603	1,654	1,791	2,029	2,450	2,797	3,694	4,387	4,780	5,582	6,146	6,428				
Hydro	100	100	100	100	100	209	209	308	327	416	461	777	811	831	850	1,200	1,905	3,254			
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	440	880
Total	1,220	1,334	1,440	1,507	1,604	1,812	1,863	2,099	2,356	2,866	3,258	4,471	5,198	5,611	6,432	7,346	n.a.				
Production (Million kWh)																					
Industrial								Gross Production													
Thermal	1,421	1,500	1,548	1,666	1,709	1,709	1,841	1,900	1,988	2,195	2,397	2,532	2,585	2,453	2,548	2,772	n.a.				
Hydro	130	104	92	98	93	99	74	75	68	78	90	99	79	91	80	102	n.a.				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	1,551	1,604	1,640	1,764	1,802	1,808	1,915	1,975	2,056	2,273	2,487	2,631	2,664	2,544	2,628	2,874	n.a.				
Public																					
Thermal	2,596	3,143	3,592	4,237	4,817	5,520	6,350	7,535	9,157	11,071	13,813	17,239	20,708	23,813	26,747	29,543	n.a.				
Hydro	193	183	208	183	205	298	392	577	469	507	915	936	1,397	1,471	2,137	2,671	n.a.				
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Total	2,789	3,326	3,800	4,420	5,022	5,818	6,742	8,112	9,626	11,578	14,728	18,175	22,105	25,284	28,884	32,214	n.a.				
Combined																					
Thermal	4,017	4,643	5,140	5,903	6,526	7,229	8,191	9,435	11,145	13,266	16,210	19,771	23,293	26,266	29,295	32,315	34,959				
Hydro	323	287	300	281	298	397	466	652	537	585	1,005	1,035	1,476	1,562	2,217	2,773	4,495	9,760	12,000	14,000	16,000
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,000	4,000
Total	4,340	4,930	5,440	6,184	6,824	7,626	8,657	10,087	11,682	13,851	17,215	20,806	24,769	27,828	31,512	35,088	39,454				

n.a. - not available.

Sources: For 1955-60 and 1971: UN Electric Energy Statistics for Europe (1959, 1961, and 1971 editions).
For 1961 to 1970: UN Series J (No. 15, 1961-1970).

Table F-46

FUEL DEMAND IN ELECTRIC POWER GENERATION IN ROMANIA
(Thousand Tons of Coal Equivalent)

Fuel	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Coal																	
Hard coal	n.a.	755	678	863	618	913	987	1,010	1,109	1,193	1,505	1,723	2,069	2,453	2,866	3,658	n.a.
Brown coal	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-
Total coal	n.a.	755	676	863	816	913	987	1,010	1,109	1,193	1,505	1,723	2,069	2,453	2,868	3,658	n.a.
Liquid fuels	n.a.	1,155	1,073	947	671	478	498	366	396	366	406	316	236	195	304	372	n.a.
Natural gas	n.a.	1,070	1,339	1,423	1,797	2,066	2,306	2,656	3,249	3,813	4,375	5,179	5,942	6,686	6,896	6,601	n.a.
Manufactured gas (gas works)	-	-	64	62	73	61	65	92	137	201	166	173	153	185	166	-	-
Other fuels (peat, waste)	n.a.	197	90	84	109	101	94	110	126	143	118	112	74	80	67	378	n.a.
Total fuels	n.a.	3,177	3,244	3,379	3,466	3,639	3,850	4,436	5,019	5,716	6,590	7,505	8,474	9,599	10,301	11,009	-
Grams coal equivalent/kWh production (gross)		684				503					407	380	364	366	352	341	
UN data		684				502					407	380	364	365*	352	341	

Source: UN Annual Bulletin of Electric Energy Statistics for Europe, T-4.

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Source AFSCR 23-50, 11 May 70

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